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BRIDGE AND TUNNEL CENTRES.

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II.

BRACING.

It is to be observed in connection with the matter of bracing, that the frames should be arranged in such wise that no piece suffers any strain other than *compression* or *extension* in the direction of its length. As it is, however, by no means an easy matter to make the distinction, we shall give the following rule to which there is no exception:

Suppose we have two beams abutting against each other at their upper end, and loaded at their point of intersection with a weight. Take notice of the *direction* in which this *straining force* acts, and *from* the point *at* which it acts draw in this direction a line representing by its length the intensity of the strain. From the remote end of this line draw lines parallel to the two pieces on which the strain is exerted. The line drawn parallel to one must of necessity cut the other or its direction produced. If it cut the *beam itself* the piece is *compressed*, and acts as a *strut*. If, on the other hand, it cuts *the direction of the beam produced*, the piece is *stretched* and acts as a tie. We may then lay it down as a general rule in framing, that if the piece *from which* the strain comes lies *within* the angle formed by the pieces strained, the *strains these* sustain are of the *opposite* kind to that of the *straining point;* if that is *pulling*, they are pushing; if that is *compressed* they are *stretched*. Again, if the piece from which the strain comes lies *within the angle formed by the direction of the two produced, all* will have the same kind of strain; and, finally, if within the angle formed by the *direction of one produced* and the *other piece itself*, the strain will be of the *same kind* as that of the *most remote* of the two beams strained, and of the *opposite* kind to that of the *nearest*.

The object of all bracing, then, being to convert all transversal strains into others which act in the direction of the length of the beams, the frame must be divided into a number of triangles; for as the triangle, or some modification of it, is the only geometrical figure which possesses the property of preserving its figure unaltered so long as the length of its sides remain constant, it is the figure best suited for structures in which rigidity is essential for stability. But, again, some forms of triangles are much to be preferred to others; the strength of the pieces forming the triangle depending very much on the angle they make with each other. *Oblique* angles are to be

avoided. *Acute* angles when not accompanied by oblique are not so injurious, because the strain can, in such pieces, never exceed the straining force; but in an *oblique* angle it can surpass it to any degree.

In all forms of bracing, too much attention cannot be given to the joints. Where the beams stand square with each other, and the strains are also square with the beams and in the plane of the frame, the common mortise and tenon is the most perfect joint, a pin usually put through both so as to draw the tenon tight into the mortise, and so cause the shoulder to butt very snugly. Round pins are much better than square ones, as they are not liable to split the bit. Where the beams are very oblique, it is difficult to give the foot of the abutting one such a hold as to bring many of its fibres into actual contact with the beam butted on. It would, in such case, seem proper to give it a deep hold with a long tenon. Nothing, however, can be more injurious, for experience has fully proved that they are very liable to break up the wood above them and push their way along the beam. For instance, suppose the head of an inclined strut abutting on a horizontal beam to descend a little; the angle with this latter beam is diminished, by the strut revolving round the stress in the tie beam. By this motion the bed of the strut becomes a powerful fulcrum to a very long lever; the tenon is the other arm and very short. It therefore forces up the wood above it and slides along the horizontal beam. This may be prevented by making the tenon shorter, and giving to its toe a shape which will make it butt firmly in the direction of the thrust, on the solid bottom of the mortise. When the beam is a tie the joint must depend for its strength on the pins or bolts, and the iron straps placed across it.

STRIKING THE CENTRES.

Undoubtedly the most dangerous operation connected with the use of bridge centres is the process of striking them. No matter with how much care the arch may have been constructed, the drying and squeezing of the mortar will cause it to settle in some degree when the centres are removed, and this degree of settlement seems to be very largely affected by the time the centres are allowed to stand. By some it has been urged that the centring should never be removed until the mortar in the joints of the last course has had ample time to harden; others going to the other extreme have advocated striking the ribs as soon as the arch is keyed, claiming, not without some reason, that the settlement of a *well built* arch will never be so great as to become dangerous even though the supporting frames be removed when the mortar is green. But possibly the best practice lies not far from either of these extremes. It has, indeed, time and again, been amply demonstrated that to leave the centring standing till the mortar has hardened, and *then* take away all support, the mortar having become unyielding, is to cause the courses to open along their joints. To strike the centre, on the other hand, when the arch is green will, seven cases out of ten, be followed by the fall of the bridge; but by easing the centring as soon as the arch is keyed in, and continuing this gradual easing till the framing is quite free from the arch, the latter has time to settle slowly as the mortar hardens, and the settlement will be found to be very small.

It becomes necessary, therefore, to provide some arrangement by which the framing may be slowly lowered from the soffit of the arch, an operation accomplished in a variety of ways; by folding or double wedges, by striking plates, by bearing irons and screws, by cutting off the ends of the principal supports, and, finally, by plate iron cylinders filled with sand. The folding wedges are, perhaps, most commonly met with in practice, and are finely suited for arches of small span, as a sill stretching from abutment to abutment may then be used to rest them on. They consist of two hardwood wedges, about 15 in. long, right angled along one edge, and placed one upon the other in such wise that the thick end of one shall be over the thin end of the other, thus making their surface of contact an inclined plane. These wedges are placed under the tie beam of the rib and on the sill, as is illustrated in Fig. 2. It is evident that by driving the upper wedge up along the inclined surface of the lower, the rib which rests upon the upper one must rise, so that

by placing a number of these folding wedges under each rib it may easily be keyed up to the desired level, and by driving the upper down the inclined surface of the lower, the rib may gradually be lowered. To keep the under wedge in place, it is usually made fast to the sill and the surface of contact of each wedge well greased with soft-soap and black lead. When the wedges are in place under the rib, it is a good practice to mark each wedge at the point where contact ceases, so that when the centres are being lowered we may be able to know whether they are lowered uniformly or not. For instance, let the lower wedges of three pair of folding wedges project two inches beyond the end of the upper ones, and mark with chalk on the *side* of each lower wedge the point where contact ceases; namely, two inches from its end. Now, if in striking the centres the upper wedges have *all* been driven back so that the *end* of each instead of being *at* the line is one inch *beyond it*, then the frame has been uniformly lowered; but if some are one inch and some $\frac{3}{4}$ inch from the line, the frame has not been lowered uniformly, and the difference must be corrected by driving *all* the wedges till they are one inch from the chalk line.

It is evident that such an arrangement of folding wedges can be of but little use unless the horizontal beam or sill on which they rest is rigidly supported from beneath, as any yielding of the sill would be followed by a separation of the wedges and rib. In constructing bridges of wide span over creeks or rivers on which there is no navigation to be interrupted, it is usual to make use of the folding wedges and support the sill by a row of piles driven into the river bed, and it then becomes especially necessary to watch the wedges lest by some settling of the piles and sill they have separated in the smallest degree from the tie beam of the rib.

In cocket centres the folding wedges are replaced by a *sriking plate* placed at each end of the rib, and sustained by strutting or raking pieces which abut either on off-sets at the foot of the pier or on sills placed on the ground. Each plate consists of three parts, a lower and upper plate and a compound wedge driven between them. The upper of these plates is of wood made fast to the base of the rib, and is cut into a series of offsets on its *under* surface (see Fig. 4). The lower plate is likewise of wood cut into offsets, but on its *upper* surface, and is firmly attached to the raking pieces which sustain it. The compound wedge consists of a beam cut into offsets both upon its upper and lower sides so as to fit those of the two plates, and when driven between them is held in place by keys driven behind its shoulders.

Previous to the time of Hartley, the rib was struck in one piece by the use either of wedges or striking plates. To him, however, we are indebted for an improved system of striking or easing the centres by supporting each lagging upon folding wedges. When this arrangement is used the rib is firmly attached to its supports, and the laggings rest upon wedges placed between them and the back pieces of the rib. A great advantage gained by this, is that the laggings may be removed course by course from under the arch, and replaced if the settlement prove to be too great at any one part of the soffit. Another method, at one time much in use among French engineers, is to cut off the ends of the chief supports of the rib piece by piece, an operation which cannot be accomplished with much regularity, nor without much danger.

The least objectionable way of striking centres, and one accomplished with great ease and regularity is by the use of sand, confined in cylinders. A number of plate iron cylinders one foot high and one foot in diameter are placed upon a stout platform sustained by timber framing. The lower end of each cylinder is stopped by a circular disc of wood of an inch thickness fitting tightly into the cylinder, and at about an inch above this wooden bottom three or four holes an inch each in diameter are drilled through the iron sides of the cylinder and stopped with corks or plugs of wood.

Into the cylinders thus prepared is poured clean dry sand to a height of 9 or 10 inches above the bottom, and on this sand in each cylinder rests a cylindrical wooden plunger, which fits so loosely as to work with ease, and forms one of the vertical supports of the rib.

To prevent moisture getting at the sand, the joint between the plunger and cylinder is filled with cement. So long as the sand is dry it remains incompressible to any weight that may press on it, and the rib is thus kept invariably in its place. When the centre is to be lowered, the plugs are taken out of the cylinder, and as the sand runs out of each with *uniform* velocity the frame is *uniformly* lowered. This method is of especial value for centres of great weight.

The distance at which the frames or ribs of centres should be placed apart, measuring from the centre of one rib to that of the next, must be regulated solely by the weight of stone used for the arch, the distance varying inversely with the increase of weight. That is to say, if we assume some distance for stones of a given weight, say 6 feet for stones weighing 150 lbs. per cubic yard, and wish to find the proper distance apart of the ribs when the stones weigh but 120 lbs. per cubic yard, we have

150 : 120 :: 5 : 4 . Then making 6 ft. the distance for 150 lb.,

4 : 5 :: 6 : x $\quad 4x=30 \quad x=7$ ft. 6 in.,

the proper distance for stones of 120 lbs. per cubic yard. The following table has been calculated in this manner :

Weight of Stone per Cubic Yard.	Distance apart of the Rib of Centring.
120 lbs	7 ft. 6 in.
125 lbs	7 ft. 3 in.
130 lbs	6 ft. 11 in.
135 lbs	6 ft. 8 in.
140 lbs	6 ft. 5 in.
145 lbs	6 ft. 2 in.
150 lbs	6 ft. 0 in.
155 lbs	5 ft. 10 in.
160 lbs	5 ft. 7 in.
165 lbs	5 ft. 5 in.
170 lbs	5 ft. 3 in.
175 lbs	5 ft. 1¼ in.
180 lbs	5 ft. 0 in.
185 lbs	4 ft. 10¾ in.
190 lbs	4 ft. 8 in.
195 lbs	4 ft. 7 in.
200 lbs	4 ft. 1 in.

It now remains to consider briefly, the subject of centring as used in the construction of the arched roofs of tunnels. In work of this description, the span being always small, the arch light and the facilities for obtaining firm points of support for each rib as great as can be desired, all the hindrances, that so often make the framing of a stone bridge centre a matter of no small difficulty and foresight, are wanting, and the rib admits of a simplicity of arrangement at once favorable to economy of material and of space. It must, however, be remembered that although the span is small and the arch light, the strength of the rib of a tunnel centre must be much greater in proportion to the burden it has to carry than that of a bridge centre ; since the former has not only to resist the weight of the earth above it, but must also withstand the wear and tear of many destructful causes to which the latter is never exposed. In tunneling through a hill side, no matter how short the distance, more or less rock will invariably be met with, and more or less blasting must therefore be done, and the shock and flying splinters of rock which accompany each explosion do much mischief to the ribs by disturbing or injuring them. This cause acts strongly on all parts of the centre, but is especially severe with the leading ribs, which, as the brick work must always be kept well up to the heading, are directly exposed to the violence of each explosion.

A second cause of injury to the ribs, and one quite as damaging and unavoidable as the first, is the repeated taking down, carrying forward, and putting up of the ribs every time a length of arch is completed. In bridges, unless the structure is composed of a series of arches, the centring is never disturbed from the time it is first put up until it is finally *struck* on the completion of the works. In tunneling, however, to avoid the foolish expense of building centres from end to end of the tunnel, it is customary to construct but one length of twelve or fifteen feet of centring, and to move this forward whenever it becomes necessary to turn a new length of arch. Thus, for example, we will suppose that we are driving a tunnel through earth of a moderate degree of heaviness, and are, therefore, using centres consisting of two sets of laggings and five ribs, two made without and three with a horizontal tie beam. The object in making some of these ribs without the tie beam is that, by so doing, the centring may be brought close up to the heading without interfering with the raking props, which could

not be done were the beams to be retained. These five ribs are arranged in practice so that one without the tie beam shall be placed at each end of the length of centring, and between these two are the three with beams. We will suppose this to be the arrangement of the ribs in the present case, and will number them, beginning with that nearest the heading, 1, 2, 3, 4, 5. While the arch is being turned upon this length the excavation for a new one has been made, the invert built, the side walls raised to springing line and all is ready to carry forward the centring. This operation, however, must be done with the utmost caution. If the ribs are taken from under the newly completed arch before the invert and side walls of the advanced length are built, the whole piece of arch with its side walls will be almost certain to separate from the length just behind, and move forward several inches in the direction the work is progressing. If, on the other hand, after the advanced side-walls are up, *all* the ribs are taken from under the arch, this latter will be quite certain to come down in ruins, since it has to uphold not only the weight of the earth resting immediately upon its bricks, but, in addition, *half* the *weight of the earth* which presses upon the crown bars of the newly excavated length, as one end of all these bars rests upon the arch near its end. Rib number 1, then, which is directly beneath the end of the crown bars, can not be removed with any degree of safety. It is also desirable that number 3 should be left in place to help support the laggings. Numbers 2, 4 and 5 are the only ribs left, and these are to be taken down and set up forward, taking care that 5, which has no tie beam, is placed nearest the heading; the order of arrangement then being 5, 4, 2, 1, 3.

Over the rib thus arranged a second set of laggings is laid, and on them the arch is turned. When this length is completed, and all preparation made to carry forward the centring, the ribs numbered 4, 1, 3 are taken down and set up forward in the order 1, 3, 4, 5, 2, and so on till the centring reaches the end of the tunnel, or meets that coming from the opposite end of the tunnel, supposing it to be worked both ways.

Now, it is precisely this continual taking down and setting up of the ribs, that produces so much injury to them, since, in order to pass them under the forward ribs and props which remain standing, it is necessary to take them in pieces. Each rib, therefore, must be framed in such wise that it may be repeatedly taken apart and put together again without injury to its strength or to the joints of the timbers removed and replaced. Figs. 5 and 6 afford an illustration of two centre ribs arranged to meet these requirements in the simplest manner possible. Fig. 5 is a drawing of a leading or segment rib, which it will be observed is constructed without a complete tie beam at the bottom so as to offer no obstruction to the raking props. It consists of two parts or segments, which, when the rib is placed, join at the crown of the arch and along the line *a b*, and are made fast to each other by two iron bars placed across the joint at the crown, one on each side of the back-pieces, and bolted through the back-pieces as shown at *c c*. An additional band is passed around the two vertical beams as shown at *d*. To prevent any slipping of these beams along the joint *a b*, the surface of each beam is notched, as shown at *e*, and a wedge driven through the notch. When the rib is to be taken down, the band at *c c* and that at *d* is removed, and the wedge at *e* driven out, and the rib thus separated into two segments may be carried through a comparatively small space. As this leading rib is subjected to the direct effects of the blasts, and to flying fragments of rocks, its joints must be strengthened by irons placed on each side of the rib, over the joint, and bolted through the timbers as shown in the figure.

This form of rib is finely adapted for tunnel centring, as it may be taken apart without removing a single beam, while its joint is so arranged that the pressure of the arch assists in no small degree to hold its parts in place. Indeed, the only valid reason why this form of rib should not be used in every part of a tunnel centre is the absence of the tie beam, which is certainly a great security against the spreading or contracting of the span. Were this tie beam supplied, and it may easily be supplied by an iron screw rod, this form of frame would probably, in

addition to the convenience of taking apart and resetting, sustain any amount of pressure ever likely to occur either vertically or laterally, as also all ordinary wear and tear from use.

Fig. 6 represents one of the interme-

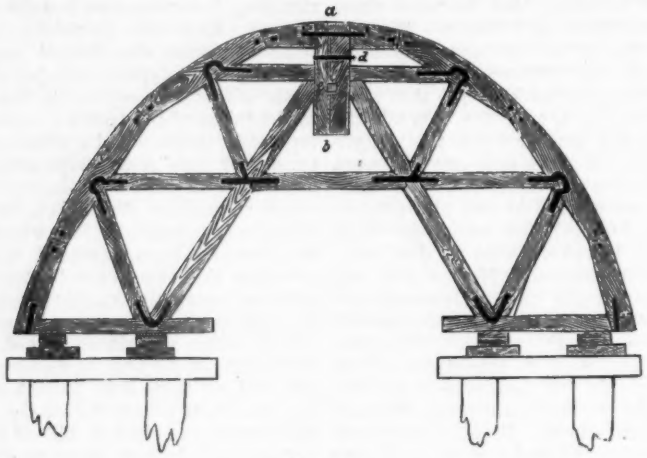

Fig. 6.

diate ribs called scarf or queen post centres, which, as there are no props to be interfered with, are provided with horizontal tie beams. As these ribs are also to be taken apart each time they are shifted, the tie beam is composed of two beams joined by a scarf joint strenthened by a piece of timber placed above it, and bound to the tie by two bands of iron as shown in the figure. The horizontal beam joining the queen posts is also movable, and is held in place by the iron placed over its joints and bolted through. In joints thus protected, the holes through which the bolts pass are liable after a time to become so much enlarged, from the repeated driving in and out of the bolts, so as to injure the strength of the joint. This may readily be overcome by using a bolt with screw threads at each end in place of a bolt with a head and one nut, so that when once driven through the beam it need not be removed.

By a comparison of these two forms of ribs, it is evident that while the queen post centre possesses an advantage over the segment form in that it is not liable to lateral spread, it is at the same time inferior to the former in many important points. It cannot so well resist shocks or side blows, and being so taken to pieces every time it is moved is very liable to be injured especially at the scarf joint. An additional recommendation for centres constructed on the plans of Figs. 5 and 6, is the small amount of material used, which is quite as small as is consistent with the varying strains the ribs are exposed to, and is so cut that the timbers are almost as valuable when the tunneling is completed as they were when first purchased for the ribs.

The estimation of the dimensions proper to give each tie and brace of the rib is easily determined in so simple an arrangement, by any of the methods given for bridge centres. It is, however, to be remembered that, while the bridge centre has to sustain but the weight of the arch stones and bonding mortar, a load which can be calculated to a pound before one stone is laid, the centring of a tunnel has to resist the pressure not only of the brick roof, but also of the earth above, and that this latter pressure is wonderfully variable. The pressure of the brick work will of course vary when laid in cement and when laid in mortar. From the most careful experiments made to determine the weight of a cubic yard of brick work, we find that when the

bricks are laid with cement the weight per cubic yard is 2,897 pounds, or in round numbers 2,900 lbs.; when laid in mortar beds the weight falls to 2,677, a difference of some 220 lbs. per cubic yard. It is true that the pressure of the earth does not act to any great extent on the centring, until the arch is turned and the crown bars drawn forward to form the roofing of the newly excavated length, but when this is done, and the three ribs removed to be set up in advance, the pressure on the two ribs remaining under the arch is quite severe. This load is especially variable with the leading or segment ribs, which it will be remembered are placed at the ends of the length of arch, and sustain one end of all the side and crown bars supporting the earth, and the movement which this earth is at any moment liable to take, cannot be foreseen. At times a whole length can be gotten out and the arch turned without any perceptible motion of the earth either at the sides or on top; at others, the earth will of a sudden begin to move and throw all its pressure on the side bars; then, again, the action will take place at the crown and become so great as to press the bars down in the middle through a distance of many inches, or even to break the stoutest 15-inch oak beams.

This action of the earth, however, seems to be controlled by law, since it depends largely on the depth of the tunnel below the surface. The pressure on the sides is most severe in those parts of the tunnel which are deepest, and the vertical or crown pressure (and this is always the severer of the two) where the distance below ground is less. At first thought this is precisely the reverse of what we should expect to be the case, for it seems but natural to suppose that the greater the depth of earth the greater the pressure on the arch beneath. The facts are, however, quite the contrary. Thus, for example, in excavating a tunnel through a hill, as we enter the hill side the pressure is almost exclusively at the crown and very severe; as the work progresses nearer and nearer the centre of the hill where the amount of earth above the arch is greatest, the vertical is changed to lateral pressure, and this latter is in turn changed to vertical as we approach the other end. This is well accounted for, by supposing that in the former case the depth of earth being small, the whole of it gets into motion and acts vertically downwards, while in the latter case the amount of earth being great only a small portion is put in motion.

The leading rib, then, must be constructed with no small care, and its joints well strengthened. For tunnels of ordinary span, whatever may be the curve of soffit, we may with safety give the parts the following dimensions. The backpieces two thicknesses of 3 in. plank; the planks breaking joints with each other. For the segment rib make all the braces 6 in. $\times$ 6 in.; the long struts reaching from the half sills to the crown 7 in. $\times$ 6 in., and the vertical pieces at the crown forming the joint $a\,b$ also 7 in. $\times$ 6 in. For the queen post centres, make the tie beam 9 in. $\times$ 6 in., as also the short timber placed over the scarf joint; the queen posts 6 in. $\times$ 6 in., excepting at the upper and lower ends where the braces abut which should be $10\frac{1}{2}$ in. $\times$ 6 in.; the short piece between the queen posts, and just below the crown 4 in. $\times$ 6 in., and, finally, the braces 6 in. $\times$ $5\frac{1}{2}$ in.

The manner of setting the ribs is illustrated in Figs. 5 and 6. Under the queen post ribs is placed a long horizontal beam, its two ends resting on the side walls and supported immediately under the foot of each queen post by vertical posts. Upon this beam are placed longitudinally four thick planks, and on these rest the folding wedges. The segment ribs are supported in much the same way, each rib by two short timbers, one end of each resting on the side walls and one on a vertical post under the heel of the rib; on these rest the longitudinal planks which are placed, however, a little oblique to the tunnel since the heel of the segment rib is not so far from the wall as the foot of the queen post.

It has already been remarked that it is never wise to strike the centres until the side walls of the newly excavated length are up, as in work of this class there is a strong tendency to move forward in the direction of the excavation. If, however, the ribs are struck in the manner already described, with the laggings of the back length kept tight up to the arch by the two frames left under

them, we shall always have two lengths of completed work remaining with their supports, not only until the next length is excavated but till the side walls are built and ready for the ribs. Under such circumstances each length is well able to uphold its burden till it receives assistance from the next advancing one, the construction of which to springing line occupies several days, and the cement or mortar has time to harden before the weight comes upon the arch after striking the centring. When, however, from false motives of economy, only three ribs and one set of laggings are used, the entire support of one stretch of arch must be removed before another can be commenced, and this, again, before a third is turned, leaving the green arch unsustained, in which state it is liable to give way, the bricks to crush and the whole arch to come down in utter ruin. Nowhere, indeed, among all the variety of engineering works will a penny wise economy more surely prove a pound foolish one than here; nowhere else will an unwise saving lead to so profuse an outlay.

Tunnel centres again differ from those of bridges in that the laggings are very differently adjusted. In the later case it is the custom in practice to place all the laggings on the ribs before commencing to turn the arch, by which means no small degree of stability is given to the ribs. In tunneling, however, where only a few inches of space remains between the backpieces of the frame and the poling which sustains the earth, it would be utterly impossible to turn the arch if *all* the laggings were put in place before the brickwork is begun. To overcome this difficulty, only a few laggings, say five or six are placed at a time. Thus, starting at the springing line, we adjust six laggings on each side of the frame, and carry the arch up equally on both sides. When it has reached the upper bolster, we add six more, and the masonry continued as before, and proceed in this way until very near the crown as shown in Fig. 7, where A A′ is the brick

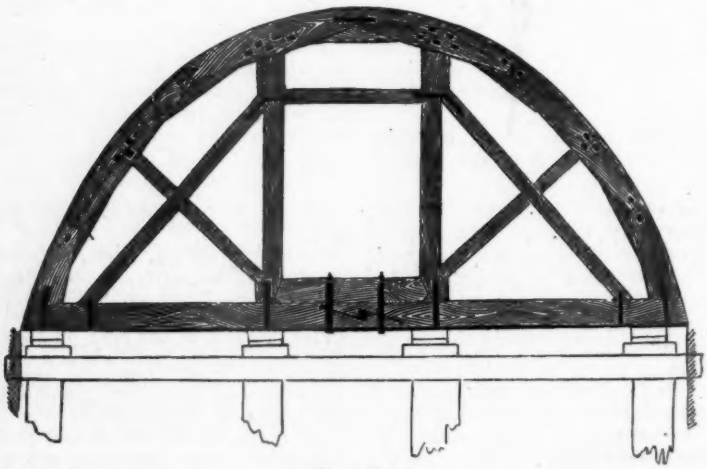

FIG. 7.

work. At this stage of the work the two laggings C C′ are placed on the ribs, the top of their inner edges being first rabbeted as shown in the figure. In these rabbets "*cross*" or "*keying-in*" laggings B, consisting of stout planks 18 or 20 inches in width, are laid one at a time beginning at one end of the centring. The bricklayer whose duty it is to key-in the arch stands with his head and shoulders between the brickwork A, A, and starting at the end of the last piece of completed arch places the first *cross* lagging, and keys in the arch over it; then a second, and in like manner keys in the arch over it, and thus re-

treats along the entire opening until the whole length of arch is keyed in.

Among the varieties of patent centres that planned by Mr. Frazer, affords a most excellent specimen, and both from its strength, economy, ease of shifting and the small amount of space it occupies in the tunnel, has met with much approval from the engineering profession in England. This centre consists of but three ribs each differing from the other two in design as shown in Figs. 9, 10

Fig. 9. Fig. 8.

and 11, of which 9 is the leading, 10 the middle and 11 the back rib. Each rib is constructed of four pieces of timber four and one half in. thick by 16 inches wide, scarfed together as shown in the drawings. In centres of the ordinary construction, the ribs when the laggings are laid upon them are all of precisely the same size, and of the same span and rise as the soffit of the intended arch. In Mr. Frazer's plan, however, all the ribs differ in the length of their radii; the radius of the outer curve of the leading rib (Fig. 9) being greater; that of the middle 3 inches less than, and that of the back rib yet smaller than the radius of the soffit; so that the middle centre is the only one of the three which acts in the same way as the ordinary centre frame, that is to say with the laggings and arch resting immediately upon the rib, and is consequently with the laggings on it of the same rise and span as the arch.

The leading rib has for its outlet edge a radius 12½ inches larger than that of the arch soffit, and for its inner edge one 3½ inches less than the same radius (thus making the 16 in. thickness) and is plated on both the inner and outer surface with half inch iron plates bolted quite through. The plate on the inner surface is six inches broad and projects 2 inches over that side of the rib which is turned towards the middle rib, thus forming a flange on which the laggings rest (see Fig. 9). When this rib then is in place, it must be its whole thickness in advance of the end of the intended arch, and as it stands 12½ inches above the soffit will cover 12½ inches of the toothing ends of the brickwork, thus forming a sort of mould to guide the toothing.

The middle rib (Fig. 10) is also covered on the under surface with half inch plate iron in one piece and bolted through as shown in figure, thus giving the rib the strength it would have if supported by the usual struts and braces. The laggings rest immediately upon the upper surface of the rib, and therefore the radius of this side must be the same as that of the arch soffit, less *three inches* to allow for the thickness of the laggings.

FIG. 10.

FIG. 11.

The back rib (Fig. 11) is covered on the under surface with a coating of half inch plate iron in one piece, which is bolted through as in the case of the middle rib. Between each bolt a hole is made quite through the rib and its plating, and in it is placed the stem of a bearing iron. There are as many of these irons as there are laggings, the object of using them being to support the laggings which it will be observed do not rest on the rib but on the projecting irons. The amount of projection is regulated by means of adjusting screws, by screwing which the laggings may be raised to the required level, or by unscrewing lowered one by one from the arch when completed. These last two ribs are permanently attached to trestling by brackets, straps and bolts, and the trestling in turn mounted on iron rollers which run on half timbers laid longitudinally as a kind of tramway. They are also steadied at the crown by long iron hooks attached to one rib and fitting into eyes in the other.

The leading rib is supported upon slack blocks placed on top the brickwork of the side walls and by the prop A. This prop, to allow for any inequalities of the invert on which it rests, is mounted at the lower end on a screw by which it may be raised or lowered.

In setting this patent centre, the leading rib is first brought forward into place and wedged up on the edge of the brickwork to its desired level, and the prop A screwed up tight under the heel. The trestles bearing the middle and back ribs are then rolled forward till the middle rib is at the proper distance from the leading one. Three pairs of wedges are then placed between the bottom piece of the trestles and the tramway, and the trestles thus wedged up until the top of the middle rib is on a level with the flange of the leading one, thus giving two level bearings for the laggings. The bearing irons of the back rib are then pushed out by the adjusting screws until the top of each of them is also on a level with the flange of the leading rib. The three bearings then, of each lagging, when the ribs are thus arranged is first upon the flange of the leading rib, then upon the middle rib itself, and finally upon the bearing irons of the back rib. When this centre is to be again moved forward on the completion of this length of arch, a fourth rib called the "*jack rib*" is first fixed under the laggings in the rear of the back rib, this last named rib consists simply of a band of iron 1 inch thick by 2½ wide, bent into the shape of the arch. Opposite every alternate joint of the laggings a screw passes through the rib, and is furnished on its outer end with a square head similar to that of the bearing plates of the back

rib, and on its inner or lower end is a loop so that it may be easily turned with a lever. The object of placing these screws opposite each alternate joint is that by this arrangement only half as many screws are needed as there are laggings. The jack rib is itself supported at each end by an iron bar 2 feet long driven temporarily into the wall.

As soon as this latter rib is adjusted to take the ends of the laggings, the wedges are driven from under the trestles and its rollers thus brought down upon the tramway prepared for them. When thus lowered, it is evident that the two ribs (middle and back) will be so much below the leading rib which is left standing that they will easily pass under it. The trestle and its ribs is then moved forward until the back rib is within 8 inches of the ends of the laggings, when it is wedged up as before. The bearing screws are then screwed up tight against the laggings, giving these latter the same support hitherto obtained from the leading rib, which now stands between the middle and back rib. The wedges under the ends of the leading rib (see Fig. 9) are then removed and the rib carried forward over the top of the middle rib and adjusted, as previously described, on the top of the newly built side walls. The laggings are then drawn forward one or two at a time as they are needed, beginning at the springing line.

The great advantage which these patent centres appear to possess over those of the ordinary construction, is the total absence of all struts, ties and braces, thus leaving a fine open space for the scaffolding and materials of the masons. The amount of repairs also is very trivial, as they are not so liable to be injured by flying rocks. In point of economy, though the first cost of patent centres is much greater than that of the segment or queen post centres, the amount expended in repairing the latter soon makes up the difference. In point of strength, it must be acknowledged that, when working through heavy earth, the patent centre of three ribs is by no means so reliable as the all-wood centre of five ribs and two sets of laggings, used as above described. And this is certainly a serious objection in that, it is impossible to tell beforehand at what moment, owing to a fault or to the displacement of the local beds, the character of the earth may change completely from a light soil to one of great heaviness.

EMBANKMENTS AND RESERVOIRS—THEIR FAILURE, AND SUGGESTIONS FOR THEIR CONSTRUCTION.

From "The Building News."

We alluded sometime ago to the recent calamitous failures in the south-western districts of England, occasioned by the late floods; and we hinted their cause and remedies. The great importance of the subject urges us to revert to the question, to recall some of the weak points and to discuss the modes of construction usually adopted. A great diversity of opinion exists among engineers as to the mode of construction—so great indeed, that every engineer has his peculiar views of what should be the form and the materials adopted. A variety of considerations should determine in each case, the plan, form, and materials of embankments. They have to sustain the depth or pressure of water, to withstand the abrasion caused by the normal condition of wind, waves, and tidal currents. The materials along the locality of the coast or river have to be used to the best advantage, and the cost of land and maintenance must be considered. Again, long slopes towards the water offer least resistance to the action of the currents, and are less liable to injury, than more vertical ones; on the other hand, they are more costly in the area of land they occupy, and in the amount of material required. They also do not impose so effectual a barrier to the waves of the sea, or high tides and floods. Slopes of steeper inclination, or

vertical faces, expose less surface to the action of the water: they occupy less ground, and cost less in material; though, on the other hand they have more direct pressure to sustain, and there is a greater re-action. The hydrostatic law that the lateral pressure of a liquid is perpendicular to the side of the enclosing walls, and is equal to the weight of a column of the liquid whose base is the side and height equal to the depth of the centre of gravity of the side—is one that has to be constantly kept in view in designing the embankments of reservoirs and canals. Under general circumstances—that is to say, excluding the effects of the waves—the depth of water only, not its expanse or area, has to be taken into account in proportioning the thickness of embankments. It is as easy to embank a foot or a few feet depth of the Atlantic, as it is to embank a canal of the same depth, the difference being in the former case there would be more wave force and abrasion. The same lateral pressure exists in both cases. Let us here speak first of the forms and materials of river and coast banks, and secondly of tidal action and currents. Engineers differ greatly as to the best kind of slope. In reclaiming fore-shores from the sea, the banks are made from 3 to 4 or 5 ft. above the high water of the spring tides, their width being 4 ft. to 7 ft. at the crown. These banks are best curved to a convex form to the water, and no angular or sharp projections should be allowed. In Holland, the sea slopes are generally inclined slightly to the horizon, or made as flat as possible. It is evident this is a question that must depend mainly on the material and the area of enclosure. Col. Emy, an authority, has advocated a section of bank in which the slope is concave as the best to resist the action of the waves. Others prefer straight slopes, as the angle of repose of the material. In flat slopes, sand and silt may be made available, and, as we have seen, such slopes offer less resistance to the tide. Tidal action is greatest at the lowest high tides of the neaps. For inner slopes, the Dutch, who have great experience in these works, made the batter about 4 or 5 to 1.

The fascine banks of Holland may be noticed. Brushwood twigs of about 4 in. diameter are tied by others at intervals. These fascines are from 8 to 13 ft. in length, of about 1 ft. 8 in. girth, the small and large ends being placed together alternately. In other cases the fascines are placed horizontally, the ends of one layer being successively within the lower one so as to form a slope, the whole being tied by stakes driven through each, which are hooped round at the head. Sand, clay, shingle, or gravel, is rammed between each layer. A batter of $\frac{1}{3}$ or 1 to 1 in height is given. In many parts of our country, as in Wales and the North, rubble facing should be used as the cheapest and best material. The stones should be larger and be laid to a slope of $1\frac{1}{2}$ or 2 to 1; or the banks may be pitched at that part subject to erosion. Such partial facings must have solid earth or clay foundations, but we prefer loose rubble at the lower angle. A double row of piles is a good protection to the feet of these banks, with loose stones rammed between and in front. Long slopes require the least thickness of pitching. In timber districts, where rubble is costly, the banks may be protected by timber or plank facings. The guide piles are driven slightly inclined, whaled at the top, and planked horizontally inside, the earth being rammed against the planks. Occasionally diagonal piles are driven in the bank to help the piling. The Piedmontese engineers use a temporary defence of sloped piles supported by strutting and planked against the water. But the use of concrete as a substitute for stone or timber must eventually become general. A concrete backing faced with rubble, or dressed to a batter, makes a good and impermeable defence. In the Medway it has been adopted with success, and its cost is such that, wherever local materials are wanting, it offers the best alternative.

One fertile source of floods in lands enclosed by these banks is the difficulty in discharging the water during variable states of the tide, owing to the sluices of the outfall drains being closed by the head of water against them. These sluices should be of such area and frequency as required by the propable contingencies of tide, and should be hung so that the pressure of the land waters

may readily open them. We believe half our reclaimed land is deluged on account of inadequate provision in this way. A sluice of eight feet wide to 60 or so acres is considered sufficient, and we think a sluice working on a vertical axis shutting against a rebate, and having the axis fixed so as to make unequal openings to prevent the tidal water from entering under pressure, is one of the best kinds. In all tidal rivers like the Severn, it is of frequent occurrence that the mouths get choked up by the rising of the tide for a considerable period; and, when this takes place at the time of heavy storms, the danger of inundations is imminent.

The action of waves is another great cause of disturbance to embanked lands. On the coast of Scotland the fury of the Atlantic produces an average pressure, Mr. Stevenson found, of 611 lb. per square foot; and on seacoasts this must be added to the depth-pressure. Concrete blocks alone seem to withstand this action, which is greatest at half-tide. Slopes help much to diminish the impetuosity and power of waves, and we may take the section of the Plymouth Breakwater as a good type of construction.

The Dutch dykes may be taken also as good examples; in some of these, the body of the embankment is of earth, with a core of fascines and with a facing of rubble.

Puddle between sheet-piles, or an earth bank behind vertical sheet-pile facing, is sometimes adopted. A good plan is to form a loose rubble core in the water slope with rubble at the base. When sheet piling is used, inclined piles driven into the embankment or shore, to resist the pressure, may be desirable. One necessary precaution in vertical sea-walls which more effectually resist the action of waves is a good impervious foundation, as we have before said. The waves in this case have the effect of undermining the defence, and therefore the footing should be well-founded and consolidated. The bursting of the Holmfirth reservoir in 1852, when 100 lives were suddenly lost, arose from a leakage or spring in the seat of the embankment; and the Bradfield reservoir failure, still in the recollection of our readers, was simlarly undermined through insufficient puddling. The crowns of embankments are, as a rule, not carried sufficiently high to resist unusual floods, and the water, once it gets the upper hand, soon softens and disintegrates the bank, disturbing the backing and causing settlement. There are some points, too, that require higher banks than others, as when a sudden bend occurs, or a confluence or eddying of currents exists; and for this reason it is imperative that the character of the sea-coast, or the general curve of the river, should be preserved in the outline and section of any artificial embankments. Sloped banks increased the ascensional force of currents impinging on them, and this we know is not taken into account as a rule. Such banks should, therefore, be made higher than vertical or abrupt banks. There is a certain angle of surface with the horizon at which this rise attains a maximum.

The law of tides, as derived from astronomical theory, is considerably modified by local and other disturbances, as the configuration of the coast, winds, &c.; and frequently the neap or quadrature tides rise as high as the spring tides, or those happening at the syzigies. Thus we know, from personal observation, that on the coast of Hampshire the neaps occasionally equal the spring tides in height by the action of gales. Again, the sectional form of coasts increases the height of the tidal flow where it rises higher than in the open sea.

At Chepstow, the spring tide is said to rise 60 feet, and at Bristol 40 feet, while in mid-ocean islands it is not perceptible. Rivers form capillary-like funnels, which augment the height and duration of flood-tides along their flow, and thus we find them dangerous inlets when banks are low, or the natural level of the river is nearly on a par with the adjacent country. At Southampton, Christchurch, and some other places, a double tide is experienced. The double tide of the Southampton Water is a remarkable instance of the return or ebb tide being met and driven back by the larger tidal wave which flows up the wider channel of Spithead. Thus the smaller current, which is a branch of the great Atlantic wave, loses its velocity along the Western side of the Isle of Wight, and at its fall down the estuary of Southampton is met by the great-

er weight which proceeds up the wider or Spithead entrance on the eastern side of the Isle of Wight. While affording admirable facilities for ocean steamers leaving Southampton docks, by delaying the fall of the tide, this double tide acts with fatal power in low-lying districts by blocking up the outfall of the fresh storm and land waters. Colonel Emy has noticed the "bore," or the interference of the tidal wave by contractions or bars in the beds of rivers. It is really a similar meeting of waters, causing a sudden rise at a certain point; and in the Severn, along which the floods have done so much damage, this rise is considerable. But the ordinary cause of flooded districts is owing to the opposite flow of the land waters and the tide. They meet somewhere in the river, and if the volume of outflow happens to be great, the rise of the water in long rivers is considerable, and the effects disastrous. Having spoken of the action of the tide, let us briefly refer to the effects the currents of rivers have upon their banks and beds. An erosive action is constantly going on in one part or another. In steep parts, the tendency is to deepen the bed, and the excavated detritus is deposited in creeks and bays or in sudden bends, tending to fill these up. Again, in the outfall portions of rivers, the silt or sand is spread over the bottom, for the velocity is diminished, and the power of transporting materials is less. Thus we have the delta of the Mississippi causing the mouth to be silted up. The banks of a river of ordinary flow corrode more than the bottom, and here we find the greatest irregularities and deviations in most of our rivers. We also find, in observing our river courses, that a resisting bank on one side produces a concavity on the other bank. An obstruction, or sudden projection, similarly, has the same abrasive effect, the stream turning against the opposite shore. Again, we find the river deepest along the steepest bank. Along a concave bank, the stream deepens the bed, and the silt is deposited on the convex side.

By a system of impervious banks we increase the scour, and, therefore, the depth of a river. Planting willows or osiers along the banks of wide rivers, so as to give them an equal width of waterway has had a good effect; banks are formed by the deposition of the sedimentary matter and sand round the roots. In a like manner, a species of groins or spurs placed at right angles or obliquely to the stream, is sometimes used, but longitudinal banks are least expensive and most effective in their action. The penned-up lands should have waste weirs to allow the freshets to escape, and, we imagine, in some of our inundated districts the outfalls have been insufficient for extraordinary storm-waters. We may here briefly refer to a very important point affecting the safety of our water defences—namely the formation of shoals. At the junction of streams or rivers shoals frequently occur owing to the difference in the specific gravities of the fresh and salt water, to velocity, and other disturbances. The deltas of our great rivers, arising from the deposit of alluvial matter at their mouths, diminished velocity, and interference of the outflow by the tide, are instances of obstructions. Mrs. Somerville, in her admirable work, notices the interference of the outfall of main streams by increased freshets. The Rhine was once reversed in its flow by this cause, and the Mississippi is much subject to interference in its flow by the Ohio. Alluvial deposits between the latter rivers have formed an elongated island, and attempts have been made to build a city upon it. In placing a dam across a stream to close it, it is found that the best situation for it is not at the embouchure or point of junction, but at some distance above, so that the deposits may render it impervious. These deposits occur by reason of the stream becoming stagnant before reaching the dam. Submersible dams, made by filling caissons with stones or gravel and sinking them, may be frequently employed with great effect, for by contracting the waterway it is deepened proportionately. Sunken dykes have been employed in the delta of the Mississippi with signal improvement, and after dredging and other means have failed. We only point to these instrumental measures as useful in their bearing upon the subjects of embankments; for we think that to dam a brook or a valley, or to embank a stream just where convenience dictates, is often to open to the insidious foe miles of assailable districts and undefended banks.

PUBLIC WORKS IN EGYPT.

From "The Engineer."

It is only within the last half century that engineering works in Egypt have been promoted and constructed in a manner which promises well for their future permanency and the real interests of the country. Long previous to the time alluded to, engineering works of enormous magnitude rivalling those constructed in India during the dynasties of the Abdallahs and the Aurengzbes, existed in Egypt, but with the exception of the Pyramids but little remains of either their former grandeur or utility. With the decadence of the cities, the pleasures and wants of whose inhabitants they were intended to minister to, they fell into disuse, and shared in the general destruction and desolation which ages ago swept over that portion of the African continent. But although the nature and extent of these great works of construction can now be but guessed at by the light of some stray excavations here and there, and their successors bear but little resemblance to them in either design or execution, yet the physical condition of the country remains unaltered. Rightly or wrongly, the origin of surveying—one of the branches of our profession—is attributed to the necessity which compelled the Egyptian landowners to define their properties by some boundaries which were not liable to be obliterated by their annual natural floods.

As of old, so at present, the ever-recurring periodical overflowing of the Nile constitutes the natural phenomenon of the country. From time immemorial the efforts of the monarchs and the people have been directed towards the one great object—viz., that of regulating and rendering uniform, and turning to the best advantage, the fertilizing inundations of this mighty and mysterious river. Probably the idea and attempt also to unite the waters of the Mediterranean and the Red Sea may boast of the same degree of antiquity. The Nile being thus the most important and, in a great measure, the sole source of the prosperity and wealth of the country, it is evident that works of irrigation, and others undertaken with the object of improving the course and condition of the river, must constitute a prominent feature in Egyptian engineering. In Upper Egypt some extensive works of this character were carried out by the father of the present ruler. They comprised canals, banks, and roads, and some idea of the extent of the undertaking may be gathered from the fact that in one year the amount of the earthwork reached to nearly seventy million cubic yards. As may be expected in a country in which skilled labor is both scarce and expensive, the use of earthwork instead of masonry or brickwork will, in all cases to which it is applicable, be adopted. It forms not only the cheapest, but, when of good quality and sufficiently plentiful to render the maximum dimensions of no consequence, the best description of material for that particular class of work.

A glance at the physical contours of that portion of Egypt which lies between the mountains of Libya on the west and those of Arabia on the east, will demonstrate in what manner, and the reason why, it became affected by the inundations of the Nile. If two sections be made of this part of the country nearly at right angles with one another, it will be found that one, which may be termed the longitudinal section, has a gradient or slope which is practically identical with that of the river itself during flood time. The other, or cross section, has a gentle fall from the river banks towards the desert, so that when that point is reached the total difference of level amounts to between 13 ft. and 14 ft. The nature of the soil of Egypt renders these periodical inundations indespensable to its permanent fertility. A geological section shows an upper layer of ooze resting upon sand and gravel, which in their turn repose on a bed of clay. The substratum, moreover, is impregnated with various salts, to such a degree that if the land be not overflowed for a few years it becomes so salted as to be perfectly useless for purposes of cultivation, and remains so until it is thoroughly washed by another inundation. In

addition to the duty already marked out for the future irrigations works of Egypt, they have other functions to fulfill. Among these are the construction of banks or walls for the retaining and storing of water, not only to prevent the salting of the land, but also to raise the water so as to enable it to command land situated at a higher level. One of the oldest works of this kind was undertaken to preserve the city of Memphis. It was in the early part of the present century that the great work was commenced of forming throughout the whole of Upper and Middle Egypt a series of basins in which the floods might be successively and thoroughly utilized. In order to complete this project in an effectual and certain manner for the latter part of the country, it will be necessary to construct a canal of great magnitude, already proposed, and the line of which has been determined.

It has been recently proposed by a well-known authority—M. Linant Bey—to restore the ancient lake Mæris, which Herodotus states was an artificial lake formed to store the waters of the inundation, and distribute them as required during a season of drought, or when the floods were insufficient to irrigate the neighboring country. It is not worth while investigating the cause of the destruction of this lake, but we may briefly notice the advantages which would accrue from its re-establishment. It appears that by the formation of the necessary tanks forty-two thousand acres of fertile land would be lost to cultivation; but, on the other hand, by converting this land into water, so to speak, it would be possible to irrigate or bring into cultivation during drought, or seasons of insufficient floods nearly seven hundred thousand acres. Against this increased cultivable area must be set the cost of reconstructing the necessary banks, sluices, channels, and other works. This cost is very much enhanced by the fact that the level of the present bed of the ancient lake is nearly 27 ft. higher than it originally was. M. Linant Bey estimates that nearly thirty million cubic yards of earthwork would be required to construct the works. Provided the result would recoup the outlay, there would be no difficulty either in finding the necessary capital or in carrying out the undertaking.

Coming down to our own times, the public works constructed recently in Egypt are of a character which speaks well for the future prosperity of the country, whether they be regarded as intended to promote the fertility of the soil, the increase of intercommunication, or the interests of commerce. Until the Euphrates Valley Railway is made, Egypt will constitute, as it does now, the shortest route to our Indian possessions and to the East generally—a route very considerably facilitated by the opening of the Suez Canal. Twenty years ago there was no railway across the desert, either from Cairo to Seuz or from Alexandria to Cairo At present there is comparatively a good port at Suez on the Red Sea, while similar accommodation has been provided at Alexandria, and recently very much extended and improved. Both these towns have also been furnished with waterworks. Under the present ruler the railway system has been greatly extended, especially in the Soudan district. Sugar and other manufactories have been established, and no efforts seem to be spared to promote the welfare of a country which is renowned for its antiquity and former magnificence. A point worth adverting to in connection with our subject is whether it will be found advisable in future to resort to other means to irrigate the land than that of simply raising embankments of various heights. It is not improbable that when all the land situated at the lower and consequently more favorable level be brought into cultivation, the aid of machinery may be called in to raise the water to a height sufficient to command the land placed at a greater altitude.

RAILWAY TO UNITE GREECE AND TURKEY.—A concession for the construction of a line to connect the Greek railway lines with the railway system of Turkey has been granted to a M. Piat, an engineer, who has ceded it to M. Singros, a banker of Constantinople. The latter is engaged in treating with the Greek Government. The project of constructing a line from Patras to Athens will probably be revived.

REFRACTORY MATERIALS—ON FIRECLAY AND OTHER REFRACTORY MATERIALS.*

By GEORGE J. SNELUS, F. C. S.

From "Engineering."

It will be admitted by all concerned in the manufacture of iron and steel, that it is of the utmost importance to obtain good materials for building their furnaces, while at the same time it can scarcely be said that our knowledge of refractory materials is in a satisfactory state. With these convictions, the writer ventures to place the little information he has been able to gather upon the subject before the Iron and Steel Institute, with a view of eliciting discussion, in the hopes thereby of increasing the general stock of knowledge.

Although it is generally allowed that the ultimate chemical composition of a brick does not altogether decide its fire-resisting property, yet, it is often possible to judge from a chemical analysis whether a clay will answer for a given purpose or not.

Thus it is found that the presence of alkalies in sensible quantity, say, about 1 per cent., confers so much fusibility upon a clay as to render it unsuitable for very high temperatures. This is well seen in the analyses of clays from the Dowlais and the Newcastle district. The Dowlais clays, numbered 9 and 10, contain respectively 1.43 per cent. and 1.13 per cent. of potash, and though bricks made from these clays are used for forge purposes, yet they will not stand above one month in mill furnaces, whilst bricks from clays 11, 12, 13, and 14, last for three months.

Mr. Pattinson believes that it is chiefly owing to the presence of the rather large proportion of alkalies that the Newcastle bricks are less refractory than the Stourbridge.

Lime and magnesia exercise a fluxing effect when present, but when mixed with silica, as in the Dinas bricks, a small quantity of lime is useful as a binding material, as it can be more intimately combined with the particles of quartz than any other similar substance.

Oxyde of iron also exerts a fluxing effect, though in a less degree. It will be noticed that none of the Stourbridge clays contain over 2 per cent., but if alkalies are absent, iron oxyde may be present, up to about 3 per cent. without affecting the fusibility of the bricks in a very serious degree. This may be seen by a reference to the analyses of the well-known Glenboig bricks, and of the St. Helens' bricks. Blocks from St. Helens last well in the hematite furnaces of West Cumberland. The writer has found these bricks to bear the scouring action of the highly basic slag of a Bessemer furnace better than those from the Leeds district. If, however, the brick is required to stand the intensely high temperature of a steel melting furnace, even this small proportion of oxyde of iron becomes injurious.

Alumina appears to be singular in its action, for while it is well known to be one of the most infusible substances in nature, and the compound Bauxite, and also highly aluminous clays, as for example the Glenboig, and notably that from the large firebrick works in Maryland, are highly refractory, and ordinary clay, containing less alumina, is less fire-resisting, yet when alumina exists in small quantities in silica bricks, it appears to increase their fusibility. This may be seen by reference to the tabulated analysis and remarks attached.

The plasticity of a clay depends on the presence of combined water, and to some extent upon the proportion of alumina. Thus the Glenboig clay, which contains a rather large proportion of alumina, is frequently of such a soapy character that it is used instead of soap for washing the hands. The well-known Porcelain clay or Kaolin, is highly aluminous, and is prized chiefly for its very plastic nature.

These properties cause the clay to shrink much in drying and firing, but after having been highly fired the material then suffers much less change of volume by subsequent changes of temperature. Hence it is that Glenboig

*Paper read before the Iron and Steel Institute at Manchester.

bricks expand and contract so little upon heating and cooling, thus rendering them valuable in situations where changes of form would cause serious inconvenience, as in the regenerators and roofs of Siemens' furnaces.

Silica is also a highly infusible substance, but unlike alumina, its particles have no tendency to adhere or bind together except under the influence of the most intense heat. When, therefore, this material is used for making bricks, a building substance has to be mixed with it. This is the case in the manufacture of the Dinas, or silica bricks, which were formerly made from the Dinas rock, to which a small portion of milk of lime was added. It is now found that these bricks can be made from any pure silicious stone, by grinding it up and mixing about 1 per cent. milk of lime with it.

In the case of the ganisters, now so largely used for lining Bessemer converters, the cementing material is alumina, which is found naturally combined with the silica. But in this case the physical condition of the substance is of great importance, because it is used in the raw state, or at least without undergoing the process of burning. It is, therefore, important, that while it should not shrink much on heating, it should yet bind well together.

The peculiar black ganister of Sheffield possesses these properties in a high degree, and the writer has found none beter than that sent out by Mr. Lowood. The rock itself appears to have been subject either to extreme compression or to heat, as it has a peculiarly close texture. Sheffield has, however, by no means a monopoly of this substance, or at least of materials that answer the purpose, as Dowlais and Ebbw Vale are now both making their own from local sources. Even pure quartz rock can be made to answer, by mixing a proper proportion of aluminous clay with it. Where, however, the natural black ganister can be obtained, nothing can answer better for all purposes.

There is another peculiarity possessed by silica, which is, that bricks made from it expand when burnt, so that in making silica bricks the moulds must be smaller than the brick.

Thus, for a 9-in. brick, the mould would only be about 8¾ in. long. Every mixture, like every clay, has its own factor of expansion or contraction for the same amount of burning, and this is either increased or diminished by variation in the intensity of heat applied. The clay from which the St. Helens' bricks are made shrinks considerably during drying and burning. Thus, for a 9 in. by 4½ in. by 2⅞ in. brick, the mould is 9⅝ in. by 4⅞ in. by 3⅛ in. For Glenboig clay, a shrinkage of one-twelfth is allowed, that is, the mould for a 9-in brick is made 9¾ in. long.

Silica bricks not only expand during burning, but do so still more upon being subject to intense heat, contracting again on cooling; and this expansion and contraction is one of the most important points to take into consideration in building steel-melting furnaces. At Dowlais, the man in charge of the furnaces is expected to slacken the tie-rods above the furnace while the heat is getting up, and to tighten them as it goes down, so as to follow the expansion and contraction of the roof. At Crewe, it is attempted to make this self-acting, by the use of volute springs between the brick staves and the nuts on the tie-rods passing through them; while at Creusôt, they try to make the furnace casing so strong (by the use of wrought-iron girders for brick staves, and very strong tie-rods), that the centre of the roof must rise and fall to allow for the expansion and contraction.

Mr. Riley states that, when at Dowlais, he found the quantity of iron made in a puddling furnace was directly as the percentage of silica in the clay used for making the bricks.

Titanic acid has been shown by Mr. Riley to exist in nearly all clays, but it does not appear to influence their fusibility in any marked degree, and it probably plays the part of silica, to which it is closely allied in all its properties. As much as 1 per cent. was found in Stourbridge bricks, but only traces in silica bricks.

It need hardly be pointed out that it is not sufficient to have a good material. Great care must be exercised in manipulating it. If it is to be made into a brick, every pains must be taken to dry it gradually, and to fire it evenly, and to a proper point; while, if it is to be used

in a semi-plastic state, as in the state of ganister, it should be equally moist throughout, so as to dry evenly, and not so wet as to cause it to crack, or so dry as to prevent it binding.

But there is another practical point in the management of firebricks which is too often overlooked. Bricks are very porous bodies, and absorb a great deal of moisture, even when under cover, and, of course, much more if allowed to get wet. In fact, apparently dry bricks often contain a good deal of water, and if put into a furnace in this state, and the heat is got up rapidly, the bricks crack and crumble, to pieces. This is especially the case with silica bricks, and the writer has known instances of bricks being condemned as chemically bad, when the fault lay with those who used them without properly drying them. It is well in the case of silica bricks to actually set them as hot as they can be handled. In all cases when a furnace is first started, and especially with Siemens furnaces, a very small fire should be kept up for several hours and then very gradually increased. This plan will add weeks to the life of these furnaces.

Most blast furnace managers know and practise this very slow and careful drying of their plant, but it is too often neglected in mill and other furnaces.

BUILDING STONES.*

From "The Building News."

THE working and application of building stones date back to an early time, and the question of their relative merits, causes of decay, and means of preservation have for some time engaged the attention of scientific men. It is, therefore, no new subject I introduce to your notice, but one which I trust may, on account of its importance, prove of interest; for, next to the design of an edifice, the selection of the materials of which the building is constructed occupies a prominent place. A proper knowledge of the composition and durability of the principal material used in building can, therefore, be hardly overrated. Chemistry, geology and the study of architecture and engineering have each more or less to do with the attainment of a true understanding of the quarrying of stone and its adaptation to building purposes, and I therefore thought the Junior Philosophical Society would deem a discussion on this subject one of no mean interest. Without further preface I would classify stones employed in works of construction under two heads—viz., those suitable for foundations and those adapted for face work. In the former case, if the foundations and lower part of a building be under water, where perhaps a rapid current flows, or in the case of a sea-wall subject to the influence of powerful waves, a heavy quality of stone must be used, since the weight of all bodies when submerged is evidently reduced by the volume of water displaced—for instance, the lightest stone we have, the *Godstone Gatter* or *Reigate*, belonging to the upper greensand formation. This stone, when used on building land, weighs 103 lbs. per foot cube, but supposing the same stone used in sea water the effective weight would be only 37 lbs. to the cubic foot, since it would then be reduced by about 66 lbs., the average weight of a cubic foot of sea water. The top bed of this soft calcareous sandstone is used for scouring purposes, and it is known as hearthstone; the second bed of the quarry is used for road-making and rough-walling, and the third bed is suitable for architectural works, as it will withstand the action of fire, and is hence known as *Fire Stone*. Westminster Abbey was formerly built of it, and architects used it where lightness was necessary. Sandstones are composed either of quartz or silicious grains insoluble in water, cemented by argillaceous, silicious, calcareous, or other matter, generally consisting of about 93 to 98 of silica, with 1 to 2 of carbonate of lime. When of good quality they

* A paper read before the Junior Philosophical Society by A. T. Walmisley.

prove very serviceable, and have been largely employed in the northern and midland counties. The Cragleith and Stancliffe or Darley Dale (Derbyshire) are considered the best specimens of this kind of stone. The former has been used a good deal in the neighborhood of Leith. Many of the public buildings at Edinburgh have been made from it. It is an excellent stone. When the grains composing sandstones increase in dimensions they are designated conglomerate. The dark gray varieties of sandstone from the vicinity of Swansea, the Forest of Dean and Dundee, are heavy enough for water purposes, and weigh about 170 lbs. to the foot cube. The granite of Leicestershire is one of the heaviest stones we have. It is really a syenite, not a granite, as it contains hornblende and no mica, which all true granite possess. A heavy stone is also found in the western islands of Scotland, particularly in the island of Tiree. This metamorphic limestone is composed of carbonate of lime, with a good proportion of hornblende, or rather cocolite, a species of augite, in small nodules. As a rule, limestones are considered better than sandstones, but, in all cases where stone is continually acted on by water, sandstone is preferable to limestone, since it is not so likely to be acted upon by the molluscæa, which frequently bore calcareous stones, converting gradually the smooth face of the stone to a rough face, and leaving interestices for the water to get into and wear away the stone. In the case of a sea-wall entirely above the water at low tide limestone might be employed, as at Tiegnmouth, or above low water mark in the case where the lower part is always under water. In the construction of the Royal Border Bridge over the River Tweed, on the Newcastle and Berwick Railway, some experiments were made on various stones from quarries in the neighborhood, in order to test the resistance they offered to vertical pressure. The specimens selected measured 1 in. square in the cross section and 2 in. long, this being considered a nearer approach to general masonwork than an ordinary simple cube 1 in. in the side. The result gave an average of 195 tons per square foot. The closest grained and finest in texture bore as much as 362 tons per square foot, while the more coarsely gritted specimens, and those which had a more sandy appearance, resisted only a pressure of 67 tons per square foot. It is to be observed that no signs of yielding were apparent until 92 per cent. of the ultimate crushing weight was applied, when a gradual crumbling of grains of sand proved that they were nearly loaded to their maximum power of resistance. In almost all varieties of building, the specific gravity or weight of the stone employed enters into the calculation, as it is of the utmost importance that the amount of pressure produced by an arch, wall, or column, as the case may be, should not be underrated. As a general rule, stones should not be made to carry a weight exceeding from $\frac{1}{4}$ to $\frac{1}{10}$th of the pressure calculated from that which has crushed them in small experimental cubes. In the Royal Border Bridge the weight borne by each square foot of ashlar in the bridge was a little above 2 tons, whence it would be seen that the pressure on the ashlar in that work (in connection with the experiments made) was about $\frac{1}{10}$th of that which would crush the stone. In Gwilt's "Encyclopædia of Architecture," the pressure on the piers at St. Paul's and other remarkable structures is given at 17.7 tons per square foot on the piers of the cupola of St. Paul's, London; 13.6 on the piers of the Hospital of the Invalides, Paris; 26.9 on the piers of the cupola of the Pantheon, Paris; 27.0 on the piers of the cupola of St. Méry; 15.0 on the piers of the cupola of St. Peter's, Rome; 18.1 on the columns of San Paolo Fuori le Mure, Rome. When the base of solid remains the same, height influences their strength. A very thin stone easily fractures. The experiments which have been made with a view to discover the influence which form has on the resistance of stone have shown that the different solids, the bases of which have an equal area, resisted best as their section approached a circle, and that practically the resistance is in the inverse ratio of the perimeters of different figures with an equal area. It is also found that those sandstones which have the highest specific gravity possess the greatest cohesive strength, about the least quantity of water, and disintegrate the least under changes of the weather. It

is important to bear in mind the action of the atmosphere on various specimens of stone, especially in towns, where, in consequence of the air and the rain containing more or less carbonic and sulphurous acids, derived from the vapor of coal in combustion, every kind of building stone is acted upon thereby. This is very noticeable in the case of sandstones, which form a sort of filter, from their susceptibility of imbibing moisture; but the power of stone to absorb water to a large extent does not prove that it would not stand the frost. A stone may be durable as well as porous. Good stock bricks absorb a large quantity of water, yet few substances are more durable and resist frost better. When the adhesive strength of the particles of any stone is less than the expansive power of water when converted into ice, then common sense tells us the material would be broken by the frost; but it does not of necessity follow that because a stone takes up a certain amount of water it suffers from frost. Stone for building purposes should possess compactness and durability, that it shall not be affected by any natural agents as the atmosphere, water, heat and frost; also hardness, or the power of attrition, which enables it to resist blows and strength; or the power of resistance in every direction. The under beds in some quarries produce harder and denser stones than the upper beds, but are more expensive on account of the time, labor, and cost of blasting and removing. This, however, depends on the position of the quarry. It is almost impossible to lay down any fixed rule as to what stone should, in different situations, be actually employed. The transport of the material, expense of labor, &c., have to be considered as well as the design and external appearance. If possible and suitable, material near at hand is usually adopted, it being generally considered that stone employed in the vicinity of its native quarry withstands the effects of the atmosphere better than when removed further off. It is to be regretted that the large increased demand for building stone has been attended with a decreased care in its selection. Properly, stone should not be too hastily removed from the neighborhood of its quarry. It requires to season quite as much as timber does. There is, as it were, the sweating of the stone, and, after quarrying, it should be allowed to remain for a time in the quarry to harden and allow the quarry water to run out.

Buildings in this climate are found to suffer the greatest amount of decomposition on the southern, western and south-western fronts, generally most exposed to wind and rain. Decomposition is effected both by chemical and mechanical means—the stone applied to buildings being as subject to its action as when attached to native rocks.

Stones for building are either crystalline or stratified, and may be classified under three divisions—Argillaceous, Silicious, and Calcareous; although the components of some quarries vary very much, stone being simply an aggregation of particles composed of one, two, or more minerals—silica, alumina, lime, and magnesia, combined with acids, water, and other matter. The argillaceous, though used largely in an artificial state—as in the case of bricks—are not suitable for building in the natural state. Where clay is plentiful, brickwork is generally cheaper than stonework; but if much labor is required, stone can be used equally cheap. Yorkshire flag is the name generally given to sandstone, known as Bramley Fall, and is that most in use for paving and coping where strength and durability are required. It is a millstone grit from the carboniferous formation. The original quarry was situated near Leeds, on the estate of the Earl of Cardigan, but has been worked out for some years. There were six beds, with a total face of 34 ft. The top bed, about 4 ft. thick, was called the rag; 2nd, 16 ft. thick, and 3rd, 4 ft. thick, both producing good stone; the 4th, a red stone of inferior quality; the 5th and 6th, each 3 ft. thick, and of good quality.

Granite is an example of a silicious stone, and one now much used for engineering purposes. Though employed a great deal by the Egyptians, granite was not much used for building purposes in this country until selected by Messrs. Rennie for their bridges over the Thames. Aberdeen granite, of which London bridge is constructed, is considered superior to Cornish granite, of which

Waterloo-bridge is constructed—the former abounding more with quartz, the latter more with felspar, possessing a portion of potash in its composition, which is considered an agent of decay. Gray granite is more generally employed than red, the latter from its excessive hardness being more difficult to work.

The quartz may be considered as pure silex—$Si\ O_2$, chief among minerals, specific gravity, 2.6 will scratch glass.

The analyses of *mica* vary—color varies from gray to black, specific gravity 2.0 to 2.5.

Felspar, grayish white, or flesh-red tint, specific gravity 2.54. The felspar is the first to decompose, next the mica, but the quartz is imperishable. The coloring matter in granite is felspar. Geologists have been much engaged in settling the question whether granite should be classed as Metamorphic and not as a Plutonic rock, but opinions differ on this point. Metamorphic rocks or stratified crystalline rocks are those produced by a species of chemical action resulting in an alteration of form. They are the result of long-continued chemical, physical, and mechanical change, taking place in rock masses by which their appearance and structure becomes quite different to that which they represented at the time of their formation. Plutonic rocks are those igneous rocks which have not overflown surface, but cooled at great depths, and differ from the volcanic rocks, or those which have cooled at or near surface, by their more crystalline texture and by the absence of pores and cellular cavities. Granite is essentially an igneous rock, though it sometimes presents a bedded appearance. Most quarry workers consider it has a bed, but this cannot be true in a geological sense, the term "*bed*" being peculiar to stratified rocks, and meaning the original plane of deposition of sedimentary or stratified rocks. In setting stones of the latter description care must be taken to lay them in their natural or quarry bed, parallel with the horizon. All stone is said to be capable of bearing greater pressure when laid in its quarry bed than in any other position, but with stone formed in strata and laminated it becomes a necessity, unless a stone is enclosed on both sides by other stones laid in their natural bed, when it may be set with its laminæ perpendicular to the horizon, in the case of a vertical pressure, as the side stones prevent the side laminæ buckling out or flaking off through exposure to the atmosphere or frost; but, generally speaking, in all cases the laminæ to be properly set should lie in planes perpendicular to the pressure; and in the case of an arch stone at right angles to the line of thrust. This will appear evident if we consider the laminæ to be represented by the leaves of a book—a pressure on the back of a cover tending to buckle out the pages and a pressure on the side covers tending to bind the pages closer together. We find also that, however tightly books are packed in a bookcase, dust will wear itself in at the top or exposed edges of the pages, and so will air and water wear itself into the exposed cavities, be they comparatively large or minute, on the exposed face of a stone. Stones of a silicious nature are much less liable to decay than limestones, as decomposition generally commences with the destruction of the base. Stones composed of thin layers or plates, as slates, and some sandstones, are not so durable as those in which the texture is uniform, or the grains or concretions small, as granite in which the essential ingredients, felspar, quartz and mica, are scattered irregularly throughout the mass. When, as in the case of sandstone, the base is highly impregnated with silica, it becomes hard and seems to defy composition. As the particles which are held together are not acted on by air or water the quality of the sandstone depends upon the durability of its cementing properties. The disintegration of rocks and the combination of loose particles which rolled off the surface from exposure to the action of the air and water becoming indurated and forming compact rocks lower down, suggested the aggregation of particles by some common cement to form an artificial stone. A paper on building stones would be incomplete without alluding to its use and manufacture.

In the artificial stone, as originally patented by Mr. Frederick Ransome, broken flint suspended in wire baskets within boilers, is subjected to a strong solution of caustic alkali (soda or potash) at a high temperature, say 300° Fahr.,

under a pressure of from 50 lbs. to 80 lbs. per square inch, which in a semi-fluid state act as a medium to form a mass uniformly equal in its composition and texture. The alkali attacking the flint precipitates the earthy and foreign particles, which remain in the bottom of the vessel when the solution is drawn off; a large proportion of the silica is dissolved, and the solution can then be evaporated, as much as may be deemed necessary, to any required degree of consistency. Taking soda as the alkali, with a silica base, the following proportions—20.43 per cent. of silica, 27.05 per cent. of soda, and 52.52 per cent. water—produce a transparent solution (average specific gravity 1.6), which, on the application of a strong acid, becomes a solid mass by the precipitation of the silica. A little powdered flint is generally added for the purpose of taking up any excess of alkali which might prove injurious. The whole being worked in a pug-mill for about twenty minutes becomes a sort of granulated tenacious substance, like putty, which can be squeezed into moulds in any form required, and is capable of sharp outlines. After leaving the mould the cast is allowed to dry slowly, and then is submitted in a potter's kiln to a gradually increasing temperature, until at the end of about forty-eight hours it attains to a bright red heat, which is maintained for some time, and allowed to cool gradually, occupying altogether about four or five days. During this process the water is entirely driven off, the silicate of soda produces another silica insoluble in water by part of the soda combining with an additional portion of silex at the high temperature to which it is subjected, and the whole forms a compound possessing the appearance and character of natural stone, though harder in texture. Its application depends on the materials employed. When worked up with clean raw materials, such as sand, clay, portions of granite, marble, &c., together with a small portion of powdered flint, it is most suitable for moulding. When coarser descriptions of sand, grit, &c., are employed, grindstones of all kinds can be formed. By increasing the quantity of silica and subjecting it to a greater degree of heat, any amount of hardness can be attained; indeed the substance of the artificial stone appears to be sand aggregated and held together mechanically by the tenacious quality of the fused silicate of soda, which, during the process of manufacture, becomes intimately combined with the particles. Other varieties of artificial stone are formed with lime, or its carbonate or sulphate, as the base, and in a few instances they consist partly of organic matters combined with inorganic matters as the base. The use of silica, however, as a base supplies a compound superior in strength and durability to these productions, and more capable of resisting both impact and pressure. Sir John Hall some years ago boiled red sand with sea water for a considerable time, subjected to pressure, and obtained a substance nearly as hard as natural sandstone. Another experiment, submitting pounded chalk to heat under pressure, changed it into crystalline marble, and pounded basalt became converted under the same process into greenstone.

In Ransome's process a well-proportioned combination of silica and the alkali forms a kind of insoluble glass in the process of baking, which firmly holds the mass together, and affords protection against air or other fluid injuring the combined particles. Improvements have, since the patent was taken out, been made in the manufacture by the inventor, and the discovery has supplied a great desideratum, though it cannot, in the author's opinion, be said to supersede carved stone; but, considering the large demand there is for stone to be applied for building within a limited time prescribed by contract, the manufacture of such a material artificially is of the highest value, and capable of extensive employment where good natural stone is difficult to be obtained. It is suitable for all varieties of architectural decorations, and, when made in squares of about 1½ in. thick, for pavements, as in the case of the footpaths on the Albert Bridge over the Thames at Chelsea.

Marble and other limestones belong to the *calcareous*. This type forms the principal ingredient in all cements, and is very plentiful. Numerous statues of antiquity bear testimony to the durability and value of this class. *Limestones* sometimes consist of shelly substances cemented together, when the cement be-

comes affected, first causing unequal decomposition; but they generally consist of pure carbonates of lime and magnesia combined with other matter, and are more or less durable in proportion as they are more or less crystalline. Those employed in building may be divided into three classes—(1), the simple limestone; (2), the oolites, both containing a large proportion of carbonate of lime; and (3), the magnesian limestones or dolomites. The three principal oolites used in this country are the Portland, Bath and Caen. *Portland stone*, a white calcareous oolite or freestone (so-called because easily worked by chisel), due to its being composed of compounds of little spheres. Stone from the Portland quarries in Dorsetshire was formerly common in the metropolis, both for engineering and architectural works. Many of the city churches and public buildings are built of it. It has also been much used for steps, window-sills, copings, strings, and balusters, on account of its moderate hardness; but its use has of late years been much superseded in engineering by granite, and in architecture by other freestones. It was introduced into London at the commencement of the seventeenth century. Inigo Jones used it in the construction of a Corinthian portico to the west front of old St. Paul's; but the stone Sir Christopher Wren used in the construction of the present cathedral was of a superior quality to most of that now brought into the metropolis, as the quarries from which the stones used in buildings erected in the reign of Queen Anne was brought have been long closed, the stone being too hard to work. In the commissioners' report for 1839, they stated in reference to the Portland quarries, "The dirt-bed is full of fossil roots, trunks, and branches of trees, often in the position of their former growth. The top cap is a white, hard, and closely compacted limestone; the skull cap is irregular in texture; it is a well compacted limestone containing cherty nodules. The Roach beds are always incorporated with the freestone beds that invariably lie below them; they are full of cavities formed by the mould of shells, and occasionally contain oyster shells and beds of flint near the top. The top bed is the best stone. It is a free grained oolite, free from shells and hard veins. The bottom bed is similar in appearance to the top bed, and of the same component parts, but the stone is illcemented and will not stand the weather. A middle or curf bed occurs only in the southern-most quarries of the Eastcliff—it is soft to the north and hard to south. The good workable stone in the Eastcliff quarries is generally less in depth than is met with in the same bed in the Westcliff quarries, but the Eastcliff stone is harder, more especially to the south of the island. The bottom part of the top bed in the Westcliff quarries becomes less hard and durable towards the south. The stone in most of the quarries, and sometimes in the same quarry, varies considerably in quality. Such stone as contains flints, or is met with below layers of flints, is inferior and will not stand the weather. The bottom bed in the Westcliff is not a durable stone, but has been worked to a considerable extent, and sold as a good stone in the London market. In every freestone bed the upper part is the most durable and hardest stone. The best stone is in the north-eastern part of the island, the worst in the south-western. The most durable stone has its cementing matter in a solid and half crystalline state; in the least durable stone it is in an earthy and powdery state." Much of this stone, rejected in the building of St. Paul's Cathedral as unsuitable, has since been sold by contract for building. Concrete buildings have of late been tried in some places. While all must admit that a good natural stone building surpasses that of any other material, it may be questioned whether a concrete building, or at any rate one of artificial stone, would not be preferable to a bad natural stone edifice. *Whitbed* is the stone known in London as brown Portland. The so-called best bed or base bed is not the best, although the name would lead you to think so. The Whitbed is rather a darker color than the base bed, but not so fine in texture, and liable to have unsuitable cavities in it, which have to be stopped when the stonework is cleaned down. Among the numerous works built of this bed may be mentioned the new Foreign Office, Holborn Valley Viaduct, and many of the edifices on

the Duke of Westminster's estate. If carefully selected it stands the weather very well, though rather more costly to work. The base bed has been more used in London for external work than it ought to be. It costs less to work and makes a better appearance when first finished, but its use should be confined in London to internal work, or such portions as are not exposed to the weather. The Roach bed, which is found incorporated with the Whitbed and base bed, and is called respectively Whitbed and base bed Roach, is hard, strong, coarse and durable. This latter was used on Portland Breakwater. *Bath stone*, quarried in the county of Wilts, at Box Hill, Corsham Down and Farleigh Down, also in the county of Somerset at Combe Down, belongs to the oolitic series, being almost wholly calcareous, and though comparatively soft when taken out of the quarry afterwards becomes hard and serviceable. It is largely employed for the facings of buildings. Combe Down is quarried on the down from which it takes its name, near Bath. It was used for the restoration of Henry VII.'s Chapel at Westminster, between the years 1808 and 1821, but needs to be selected with great care, the blocks being occasionally subjected to vents which will not stand the effect of the London atmosphere. The major parts of Bath and Bristol are built of it. Corsham Down quarries lie parallel with the Box Tunnel, and produce a stone freer from vents, fine and even in texture. A bed of stone is found below the latter known as Com Grit, a thoroughly strong stone, but too coarse-grained to please the eye. It is largely used for heavy work. Box Ground adjoins the Corsham, and is used for sills, plinths, copings. It is coarse-grained and very durable. *Farleigh Down* resembles the Corsham in texture, but has not been so much used, as the blocks average smaller dimensions. *Caen stone* was brought into London soon after the Norman Conquest, and was extensively employed for inside decoration in the Houses of Parliament, for which purpose on account of its fine even grain and color it is well suited, as it does not require half the labor necessary with Portland stone; but it does not stand well the exposure to the atmosphere of towns, though during the middle ages it was much in demand for buildings in this country. The central tower of Canterbury Cathedral, St. George's Chapel at Windsor, Henry VII.'s Chapel at Westminster were built of it. *Aubigny stone*, quarried near Falaise, near Caen, is very close-grained, and harder to work than the Caen. It is of a colder color, and said to stand the weather better. There are only two workable beds with an intermediate stratum of soft stone. *Ancaster stone*, likewise oolitic, found near the town of that name in Lincoln, was used in the construction of St. Pancras Station and Hotel, but more particularly in its own district. *Doulting and Ham Hill* are both shelly limestones and oolitic, used largely near their own districts in Somersetshire. *Painswick stone*, quarried near Stroud, is also a member of the oolitic formation, close, white-grained, rather finer and harder than the Corsham Down, and consequently more expensive to work. The *freestones of Wardour, Chilmark and Tisbury*, in the county of Wilts, belong to the oolitic formation. The Chilmark is a siliceous limestone, and was employed for Salisbury Cathedral in the thirteenth century, Sir Christopher Wren's report upon this edifice in 1668 speaks of the stone as a little inferior to Portland. At the present day the western front is slightly decomposed, but the rest of the building is in good preservation. Tisbury stone has been used in the restoration of the Chapter House, Westminster. Among the Permian magnesian limestones may be mentioned the Mansfield stone, quarried in the county of Notts. Three distinct varieties exist—the white, red and yellow—the latter from the Mansfield Woodhouse quarry. Owing to their expense they are not much in request, though very suitable for building purposes. The red and white are calciferous sandstones, the yellow a dolomite or magnesian limestone.

The commissioners appointed to investigate the different stone quarries in this country with reference to the selection of the stones for building the new Houses of Parliament, though they admitted that many sandstones as well as limestones possess many advantages in buildings, yet reccommended the magnesian limestone as the most fit and proper material, on account of its more

general homogeneous structure, and the facility and economy of its conversion to building purposes. They selected the magnesian limestone in the neighborhood of Bolsover Moor as suitable for the purpose, being uniform in structure, and containing 51.1 of carbonate of lime, 40.2 of carbonate of magnesia, nearly in equivalent proportions, with the advantageous admixture of about 3.6 of silica.

A cube of 2 in. square was found to require 596.01 cwt. to crush it, and the facility and economy of its conversion to building purposes were also in its favor. Dolomites vary very much. The Museum of Geology in Jermyn Street and the Houses of Parliament were both built of dolomite. The former exhibits no signs of decay, while in the latter it is to be regretted that much of the stone supplied was not taken from the same part of the quarry as that approved of by the commissioners. The former shows that the commissioners could not have selected a better stone, while the latter proves that care is also necessary in its selection from the quarry.

RAILWAY SAFETY APPLIANCES.

By Mr. F. J. BRAMWELL, C. E., F. R. S.

From "Iron."

The total number of deaths to railway passengers from causes beyond their own control for the four years 1870 to 1873, both inclusive, amount to 142, or an average of 35½ per annum, and the accidents which caused these deaths may be divided into seven heads, and more than half—viz., as much as 58.7 per cent. of those accidents—are due to collision, while 12 per cent. are due to the trains being turned into the wrong lines or being "split," and about 9 per cent. are due to trains leaving the rails, another 9 per cent. to defects in the rolling stock, including boiler explosions, fractures of axles and tires, and matters of that kind, and about 4½ per cent. each to accidents arising from trains breaking away on inclines and to miscellaneous causes, while not quite 2 per cent. are due to trains entering stations at too high a speed.

The first of these relate to railway wheel tires. A railway wheel (in Europe) is commonly made with a frame or skeleton either entirely of wrought iron, or occasionally with wrought-iron spokes and rim, but with a cast iron boss, and is tired by a wrought iron or steel tire. With respect to the tire, the common mode of manufacture a few years ago was to make a straight tire bar, then to bend it into a hoop, then to weld the ends of the bar together (and great pains were taken to devise a good form of weld), and then the tire being heated was shrunk upon the wheel. But after all has been done that can be done, a weld is still, it is to be regretted, a matter of uncertainty. Many accidents arose from the fracture of tires at the welds and then the engineer devised a safety appliance. But of late years the engineer has turned his attention to getting rid of the weld altogether, and this he effects by making the tire no longer in the form of a straight bar requiring bending and subsequent welding, but he makes it at once in the form of a hoop in the condition known as a weldless tire. A welded tire is now as rarely to be met with as ten years ago it was unusual to meet with a weldless tire; but although this improvement in the manufacture of the tire itself has done away with the great source of danger (the weld), there still remains the risk of fracturing the solid metal, and therefore the safety-ring is most properly retained even with weldless tires.

Another source of danger in the rolling-stock is the fracture of axles, either those of the engines or of the passenger carriages. These fractures most commonly occur at places where there is a change of dimensions. Railway engineers were among the first to discover

that the providing of adequate size was not sufficient to ensure the durability of axles and of parts subjected to similar strains, and that indeed harm might actually be done by increase of dimensions; for that the neighborhood of a large part to a small one not merely made the smaller section relatively weaker than the larger, but it made it actually weaker than if the larger one were not there; and the railway engineer found that the only way to ensure safety was to prevent abrupt change in form, and having so found he applied this safety precaution.

Under the head of accidents to rolling-stock comes the explosion of locomotive boilers. The explosions of locomotive boilers have a certain peculiarity which demand notice, but time will not permit me to enter upon so wide a subject; to show you, however, the care taken by the engineer to prevent such accidents, I may tell you what is done at the Crewe works of the London and North-Western Railway to insure soundness in their steel boiler plates. In the first place the steel made in large masses by fusion processes, either those of Dr. Siemens or of Mr. Bessemer, is proportioned so that it shall not have more than two-tenths of 1 per cent. of carbon. Such a percentage should, with pure materials give a perfectly homogeneous flexible ductile metal; and to ascertain whether this has been obtained the plates are annealed, and then they must be capable of being bent cold without the slighest sign of fracture; and any piece of the plate must be competent to stand a "punching" test—that is, a hole of five-eighths of an inch diameter being drilled in the plate. A succession of tapered punches are driven in until the hole is enlarged to 1½ inch, or as much as six times its original area, and this without any fracture of the plate whatever. Similarly steel for axles, for tires, and for rails is tested. To such perfection has the manufacture now attained that out of 500 sets of boiler plates of comparatively modern manufacture at Crewe, which have been tested, only one plate has yielded under the test.

In England, happily, we have but few single lines of railway, and collisions arising from the meeting of trains coming in opposite directions are therefore very rare. With respect to those collisions which occur from one train overtaking another, until within the last few years the appliances employed by engineers to prevent this class of accident consisted of a series of signals placed at stations and elsewhere along the line, which were put "On" or to "Danger" as each train passed, remained at "Danger" for a certain time, say five minutes, and then were put to "Caution," remained at "Caution" for a further time—say five minutes—and then were taken off, *i. e.*, were put to "Safety" or "All right." Of late years, looking at the great increase in traffic and at the varying paces at which trains run, such a time system has been considered no longer satisfactory, and the engineer therefore has resorted to the block system, which substitutes the element of distance for the element of time as a measure of safety, and this substitution he is enabled to effect by the aid of the electric telegraph. Occasionally, however, accidents do happen even with the use of the block system. A train has been known to break in half, and the first part of the train having gone past the signal box, the man there has supposed it to be the whole train, and has telegraphed back "Line clear," while in truth the helpless piece of the train was standing on the line. Accidents have arisen in this way, but very rarely. Again, men have made mistakes in their signaling. Sometimes a man has signaled "Line clear," before the train has passed. Occasionally a man who has not received "Line clear," acts as though he had.

Now, I do not suppose the engineer with all his pains will ever be able to entirely render himself independent of the due discharge of his duty by the signalman, nor of the care of others who are engaged in the conduct of the business of railways; but the engineer is always trying to improve his position in this respect, and with this object he has invented an apparatus which shall get rid of the danger arising from one of the two neglects of duty to which I have just alluded, namely, that a man who has not received the "line clear" signal might act as though he had. This particular safety appliance is of the following construction:—When a signal-

man has put his signal to "Danger" it is locked, and that lock the signalman cannot unlock, although he can apply it. It must be undone by apparatus worked electrically from the signal cabin beyond him, and thus, until he has received "Line clear," he cannot again put his signal to "Safety." Efforts are now being made to further diminish the chance of one train overtaking another by enabling electrical communication to be established between any of the signal houses and the driver of a train. This is effected by having isolated surfaces placed at regular intervals along the line with which electrical connection is made by means of a metallic brush attached to the engine, and coming in contact with those surfaces. By this means, although complete electrical communication for the purposes of conversation is not kept up, the directions "Stop" or "Go on" can be given.

Although the question of brakes does not belong particularly to the class of collisions we are now considering, yet brakes have to be discussed in connection with our subject. The improvements that are in use here all operate by applying friction to the wheels, but apply that friction to a large number of the wheels instead of only to a few, and many of the contrivances are made so as to put on the pressure promptly. Although it is probably well to be provided with a maximum power of stopping trains, such a power is not an unmixed advantage. In the first place, although the theory is that the brake shall be so applied as to let the wheels slowly revolve, in practice the wheels are absolutely stopped; they then rub along the rails, flat places are worn in the wheels, and the comfort of traveling is destroyed by the disagreeable jolting of the carriages, a jolting not felt when the brakes are applied to brake-vans and tenders only. Moreover, the rails suffer from the action upon them of these polygonal wheels. Further, in certain cases there can be no doubt that the rapid application of powerful brakes has been the means of destroying life instead of saving it. The greatest possible brake power would be an unalloyed advantage if it were under the control of a man who knew the exact nature of the accident that was happening, and who had ample time to reflect as to the best means of using the power at his command; but as, unhappily, these are not the conditions which commonly attend railway accidents, it is to be feared that large brake power, while most useful in averting collisions, will be in many cases a cause of danger when the accident is one that arises in the train itself.

I now come to the railway safety appliances which have been devised for preventing collisions at junctions; similar appliances are also used for the avoiding of collisions where railways cross one another on a level, and indeed where railways cross common roads on a level, or cross rivers or canals by means of movable bridges.

I now wish to remind you that the railway locomotive is peculiar in respect of the inability of the persons in charge to guide it. They may vary its pace, they may bring it to a dead stop, or may reverse its motion, but they cannot guide it. In this respect their powers compare unfavorably with those of the riders of horses, the drivers of horse-coaches, the drivers of common road locomotives, of traction engines, and of steam road rollers, and with the steersmen of ships; the only persons in charge of a moving machine who were in a similarly helpless condition were those who navigated balloons; but, according to an able article in the last *Quarterly Review*, the balloon is to become "dirigible." But whether balloons are to be really made "dirigible" or not, the locomotive driver will still have to depend upon others for the guidance of his locomotive, and this guidance is commonly effected by means of a pair of moving points, and these points, according to the position in which they are set, either cause the train to preserve its direction along the main line, or force it to diverge down the branch. The points being then the real implements which control the direction of the train, one sees of what paramount importance it is that the positions of these implements should faithfully accord with the signals. In truth, the principal function of these latter is to communicate to the driver through the eye the position of the points; and if this accord be not assured, it is obvious that, although the signals exhibited might not be conflicting among

themselves, their exhibition might lead to most disastrous results.

I come next to safety appliances which are used to prevent the "splitting" of trains at junctions. Force of habit has undoubtedly on more than one occasion caused an unhappy signalman to put his signal to danger to protect a train as soon as ever the engine has passed his box, and has caused him to follow that operation by the pulling of the next lever, whereby he has moved the points and split the train. And to guard against this source of danger some railway companies issued orders that a signal was not to be put to danger until the whole train had gone by; but the risk still remained, and again the engineer was at hand with a safety appliance.

With this it is utterly impossible for a signalman even to unlock the points, but until unlocked they cannot be shifted, and in this manner the danger of splitting a train is for ever at an end. The safety-bar and the locking of facing points have a far higher importance than the mere prevention of the splitting of trains at junctions, because they have done away with the danger of the points not being entirely home, and of their being disturbed by vibration and causes of that kind, and they have therefore made properly constructed facing points safe, to be run through at speed for the main or straight line. This being so, the engineer no longer fears to employ facing-points, and the ability to so use them at will may be made to greatly increase the carrying power of a railway.

I may be, perhaps, accused of representing everything connected with railway management as being in an absolutely satisfactory condition, and as being incapable of beneficial change. Let me say that this is by no means the position I am taking up. I am here, as I told you, to vindicate the engineer, not railway management, and unhappily, from mistaken policy, or from need, or from motives of false economy where need does not exist, the counsels of the engineer are not in all instances allowed to prevail, and thus it is we see certain railways neglecting their duties towards the public by not readily adopting safety appliances. With such neglect accidents ensue; and the public not having the means of discriminating between those companies which do take proper precautions and those which do not, blame the whole railway system and visit also the engineer with censure. This should not be; we should discriminate; and if we did we should acknowledge, I think with thankfulness, the care and pains which are taken by these who adopt all known means of safety to carry on a large traffic without injury to their customers.

LIME IN THE BLAST FURNACE.*

By Mr. I. LOWTHIAN BELL, M. P., F. R. S.

From "Engineering."

In a furnace about 48 ft. in height, the carbonic oxyde generated by the combustion of the coke at the tuyeres, arrives at the throat so speedily that it, with the accompanying gases, leaves the orifice of the structure at a comparatively high temperature. The solid contents filling the furnace, as a consequence, are, within a few feet of the charging plates, in a state of bright incandescence.

When limestone, in its natural state, is used as a flux, it quickly reaches, in such a furnace, a zone where the heat is sufficient to separate the carbonic acid from its calcareous base. The temperature of this region, indeed, is so intense, that not only the carbonic acid associated with the lime, but a portion of that due to the deoxydation and carbon impregnation of the ore, is reduced to the form of carbonic oxyde.

I have shown, on a former occasion, that the smelting of a ton of iron is probably accompanied by the conversion of 6.58 cwt. of carbon from the state of carbonic oxyde to that of carbonic acid. The

* Paper read before the Iron and Steel Institute at Manchester.

carbon in its acidified form in the quantity of limestone consumed, upon one occasion, in a 48 ft. furnace was 1.92 cwt. Hence, we may infer that, were there no reduction of carbonic acid to a lower condition of oxydation, we ought to find, for each ton of iron produced, 8.50 cwt. of carbon, combined with its maximum dose of oxygen.

Instead of this quantity, only 5.47 cwt. of carbon so oxydized was found in the escaping gases of one of the smaller furnaces referred to, per ton of iron of its make.

This change in the composition of the escaping gases of a blast furnace involves more serious consequences than what, perhaps, at first sight might appear.

	cwt.	units.
There is the heat absorbed by splitting up carbonic acid containing (8.50—5.47) 3.03 cwt. of carbon		9,696
The decomposition of this carbonic acid carries off the same weight of carbon which it contains, and which escapes combustion at the tuyeres, involving a further loss of		7,272
		16,968
To which has to be added the heat required for expelling the carbonic acid from 16 cwt. of limestone		5,920
		22,888

The coke consumed upon the occasion which furnished these data amounted to 28.92 cwt. per ton of iron, and the heat estimated to be afforded by its combustion, using air heated to 452 deg. C. (846 F.), was 104,012 units. The proportion, therefore, of the total heat generated, which was absorbed by the expulsion of carbonic acid from the limestone, and the decomposition of this compound of oxygen and carbon amounted to 22 per cent. Of this, 16 per cent. is due to the use of limestone, and 6 to the dissociation of the carbonic acid, produced by the reduction and carbon impregnation of the ore.

An expenditure of 16 per cent. of the heating power of the fuel, which is rendered necessary by the presence of one of the constituent parts of our flux, affords *prima facie* a strong reason why we should seek to relieve the furnace of a duty represented by about 4½ cwt. of coke, particularly as half this weight of inexpensive small coal sufficed for the purposes of the lime kiln.

I am not aware that the experience of any iron smelter justifies the belief that any approach to this economy was ever realized by the substitution of lime for limestone. On referring to the Clarence furnace books, I find, when using the same quality of coke in each case, one of the smaller furnaces (48 ft.) gave the following results :

14 Days' make per Furnace tons.	Average No.	Coke per ton cwt.	Mine Yielded, per cent.		cwt.
419	3.34	29.06	41.9	Limestone per ton	14.58
444	2.20	39.64	42.6	Burnt lime "	11.14

Other examples from furnaces of similar dimensions gave the following averages :

14 Days' make per Furnace tons.	Average No.	Coke per ton cwt.	Yield per Mine, per cent.		cwt.
404	2.65	29.31	42.0	Limestone per ton	15.89
451	2.10	27.99	42.6	Burnt lime "	11.46

In the first two cases given, the consumption of fuel is practically the same, but the produce of the ironstone (Cleveland), when smelted with calcined limestone, is somewhat better. Discarding this cause of difference, the sole advantage from the use of lime is the increased make and superior quality of the iron. In the next two examples, an improvement in production and grade of metal is also observable, along with an economy of 1.32 cwts. of coke, part of which is probably due to the better yield from the ironstone (Cleveland), as well as to a somewhat superior quality of coke received at the works, when calcined limestone was being used. In none of these instances, judging by the relative quantities of burnt and raw limestone employed, has one half of its carbonic acid been expelled.

The apparent want of reconciliation between theory and practice in the consumption of fuel, when using the flux raw or calcined, is, in my judgment, in a great measure independent of the imperfect expulsion of carbonic acid from

the latter; and further, I am of opinion that a complete separation of this element would fail to effect in a larger furnace, any appreciable good in respect to the coke required for the process.

Omitting the somewhat questionable economy of fuel exhibited by the figures given above, it is not surprising that a furnace 48 ft. high, and containing 6,000 cubic feet, should, with a make of 200 tons to 210 tons per week, be capable of doing some additional duty when relieved of that portion of its work represented by calcining the limestone. In like manner, where a furnace 80 ft. high, and containing 15,000 cubic feet, only runs 350 tons a week, and is, therefore, compared with the former, far above its work, any such relief as that in question may be regarded as unnecessary.

The objects of this communication are to show that this supposition is substantially correct, and to endeavor to reconcile the apparent difference between theory and practice just referred to.

For the purpose in question, two of the Clarence furnaces, Nos. 9 and 10, having a height of 80 ft., and a capacity of 20,500 cubic feet, were chosen. They were blown in about twelve months ago, and were working under precisely the same conditions. No. 9 was supplied with raw, and the other with calcined limestone, and after a few weeks this order was reversed—No. 10 was put on raw, and No. 9 on calcined.

The consumption of limestone per ton of iron, was almost exactly 11 cwt., which, allowing 5 per cent. of foreign matter, would represent 5.85 cwt. of pure lime, or 6.16 cwt., including impurity, had all the carbonic acid been expelled. By the time, however, that the calcined flux was reduced to 8 cwt., the appearance of the cinder indicated a similarity of composition. This was equivalent, if correct, to an admission that the lime still retained about one-half of its carbonic acid, the truth of which was proved by an analysis of the cinder itself.

Composition of Cinder—using.	Raw Lime-stone.	Calcined Lime-stone.
Silica	30.84	30.64
Alumina	25.71	25.45
Lime	30.85	31.17
Magnesia	6.93	7.23
Protoxyde of iron	.33	.06
Protoxyde of manganese	.26	.28
Potash	.28	.30
Soda	1.02	1.20
Phosphoric acid	.34	.44
Sulphide of calcium	4.09	4.52
	100.54	101.28

Parenthetically it may be observed, that no change was effected in removing silicon or sulphur by the substitution of calcined for raw limestone, a sample of No. 3 iron from each giving the following results:

	Using Raw Limestone.	Using Calcined.
Silicon per cent.	1.91	1.91
Sulphur per cent.	.038	.033

With regard to the main object of the experiment, viz., the consumption of fuel, there was literally not the slightest advantage in the use of the flux from which half of its carbonic acid had been expelled. In each case, the burden of mine (Cleveland), on a given weight of coke, remained unaltered, without any improvement in quality manifesting itself, nor was there any tendency to an increased rate of driving. The make was in each case 61 tons to 62½ tons per 24 hours, the quality averaged about 3.75, and the coke a trifle under 22 cwt. per ton of iron.

Applying the same mode of computation employed at the commencement of this paper, the separation and decomposition of half the carbonic acid in 11 cwts. of limestone, is equal to about 5,550 units per ton of iron, the necessity for which was avoided by the previous calcination of the flux. To this must be added 1,950 units, as the heat which will be evolved by the lime reuniting with carbonic acid in the furnace, which, for the present, we will assume to happen. We have thus 7,500 units of heat at our disposal, which, at the usual condition of oxydation of the gases in an 80 ft. furnace using limestone and driven with air at 485 deg. C. (905 deg. F.) represents about 1.79, say 1¾ cwt. of coke.

I propose to endeavor to explain the cause of these 7,500 units, and the consequent non-effect of their representative 1¾ cwt. of fuel.

In round numbers, calcined Cleveland stone, in an atmosphere of carbonic oxyde, may be considered as commenc-

ing to lose its oxygen gas, or in other words, to suffer reduction when it is heated to a temperature of 200 deg. to 210 deg. C., say, 400 deg. F.

Metallic iron and carbonic acid, with some precipitated carbon, are the products of this action; but if the temperature is raised from 400 deg. to about 800 deg. F., then the carbonic acid, formed by the reduction of the ore, commences to reoxydize the metallic iron formed at the lower temperature, and this proneness to oxydation by carbonic acid increases rapidly as the temperature is raised. Thus, if a mixture of carbonic oxyde and carbonic acid in equal volumes is passed over calcined Cleveland ore at a bright red heat, the latter cannot be deprived of more than one-third of its oxygen; and in like manner, if spongy metallic iron be similarly treated, it absorbs from the carbonic acid as much oxygen as remains combined with the metal contained in the ore, *i. e.*, two-thirds of that required to constitute peroxyde of iron.

From the physical laws involved in the facts as just enumerated may be inferred:

1. That there is a point in which carbonic acid will render complete reduction of an oxyde of iron by carbonic oxyde impossible.

2. That this point varies with the temperature, *i. e.*, the reducing power of carbonic oxyde is lessened by the oxydizing power of carbonic acid rising as the temperature increases.

Now, my inquiries on this very important question connected with the action of the blast furnace have led me to infer that the gases from an 80 ft. furnace of say 15,000 cubic feet, and running 350 tons per week, are saturated with oxygen, as far as they can be, when one-third of the carbon they contain is converted into carbonic acid. The temperature of the gases when cold ironstone is used, will average under the supposed conditions about 300 deg. C. (572 deg. Fahr.).

By the use of the flux, calcined as it was in the experiment we are considering, 7,500 units of heat per 20 of iron are practically added to the contents of the furnace, and the presence of this heat at once manifested itself by a rise in the temperature of the escaping gases which corresponds to something like 1,500 of the 7,500 units placed at our disposal.

I would here observe that carbon as well as iron, either metallic or in its lower stages of oxydation, is capable of decomposing carbonic acid, and that its power in this respect is also intensified as the temperature is increased.

If, therefore, where by a change in the composition of the materials, an increase of temperature in the reducing zone follows as a necessary consequence, a larger proportion of the carbon as carbonic oxyde in the gases may arise from one or two causes—either the oxydizing influence of the carbonic acid may be augmented by the change of temperature, and so require the presence of a larger quantity of carbonic oxyde to effect reduction, or the higher temperature may enable the carbon to split up more readily the carbonic acid. Whichever of these two causes is the correct one, the result would be the same, viz., an unburning, as it were, of carbonic acid, which means a large absorption of heat and consequent waste of fuel.

In the case we are considering, this waste of fuel has, of course, been met by the additional heat generated, or not required, as explained, by the use of calcined limestone, the loss on the one side being balanced by the gain on the other.

As a matter of fact, this diminution of carbon existing as carbonic acid in the gases is precisely what I found took place in the furnace when calcined limestone in the experiments already described was employed. The analysis of the gases will require repeating, inasmuch as their ascertained composition accounted for rather more loss than the heat which had been added in the manner described.

There is, however, no reason for delaying the communication of these later trials to the Institute. They extended over a period of six weeks at the two furnaces, and the unmistakable conclusion arrived at was, that the expense of calcining the limestone was unaccompanied by any advantage whatever in the operation.

I may add that the presence of caustic lime is supposed, by virtue of the power it possesses of absorbing carbonic acid, to produce the same effect as if this acid were introduced in the form of carbon-

ate of lime. Now lime, in some form or other, exists in calcined Cleveland ironstone to the extent of from 7 to 8 per cent., and magnesia of from 4 or 5. I was therefore anxious to ascertain whether these earths were able, in any high degree, to absorb carbonic acid in the cooler portions of the furnace, and, in consequence, to carry it down where, by its reaction on carbon, a loss of coke would ensue. I would remark that lime and magnesia possibly exist in the native Cleveland ironstone, chiefly combined with silica or alumina, or both; certain it is that the carbonic acid in the raw stone is only about sufficient to form a carbonate with the protoxyde of iron present.

Whatever may be the form in which lime exists in the ironstone in its natural state, when calcined, a mere trace—under 0.2 per cent.—was washed out of the calcined ore by chloride of ammonium, and of this a portion was probably soda or potash. The ironstone (calcined), the size of mustard seed, was exposed for 25 hours, at ordinary temperatures, to carbonic acid. The original ore contained .85 per cent. of this acid, and at the termination of the experiment it contained 1.22 per cent. A second sample was similarly treated in a tube immersed in a bath of melted zinc, having a temperature of probably 800 deg. to 900 deg. Fahr. The carbonic acid it contained at the end of 2½ hours was .77 per cent., after which no change of weight took place.

These experiments prove that the presence of lime and magnesia, as they are found in calcined Cleveland ironstone, are inert so far as any absorption of carbonic acid is concerned.

Physically it would be possible, by a previous fusion of the ironstone with the flux, to render the lime of the latter incapable of absorbing carbonic acid to any extent, which acid would be expelled by such preliminary treatment. There are, however, practical objections to such a course of procedure. Firstly, in a properly constructed blast furnace, say 80 ft. high, with a capacity of 15,000 to 20,000 cubic feet, we have seen the total expenditure of coke, entailed by the presence of the carbonic acid of the limestone, is only 1¾ cwts. There is, therefore, no margin to meet any expense which would accompany the operation referred to. Besides this, the altered mechanical condition of the ironstone makes it much less susceptible to the reducing influences of the gases of the blast furnace.

I obtained the following results from specimens of Cleveland ironstone calcined to various degrees of hardness but broken from the same lump. They were exposed simultaneously in the same piece of apparatus during eight hours to a current of carbonic oxyde, at a temperature of nearly 800 deg. F.:

Specimens of Ironstone.	Loss of original oxygen per cent.	Deposit'd carbon per 100 of iron.
Burnt to brick red.....	56.1	5.6
Burnt to brown, not fused.....	65.2	21.5
Burnt to dark purple, very slightly fused.....	52.6	8.8
Partially fused.....	30.4	1.5
Fused.....	23.9	.51

Mill cinder which, in mechanical structure, would closely resemble ironstone fused with limestone, only lost 1.35 per cent. of its oxygen during 3½ hours exposure to a red heat. It contained no deposited carbon.

A specimen of properly calcined Cleveland ironstone, and a specimen of mill cinder were placed together during 48 hours in the escaping gases of a 48 ft. furnace. The former lost 52.3 per cent. of its oxygen and contained 2.42 of deposited carbon per 100 of iron; the latter only lost about 16 per cent. of its oxygen and had .25 of deposited carbon per 100 of iron.

These trials prove conclusively that it is best to use ironstone burnt so as to admit ready access to the reducing gases, and that if this be not attended to, the mine will arrive at a point in the furnace where the carbonic acid resulting from its deoxydation will be split up or unburnt by contact with highly-heated carbon, in the same way as happens when this acid is supplied by the limestone.

NEW BRIDGE IN PARIS.—The works for the new bridge joining the Boulevard St. Germain, with the Ile St. Louis, with an extension to the Quai St. Paul, are being pushed forward; and it is expected that the bridge will be opened at the beginning of next winter.

THEORIES OF VOUSSOIR ARCHES.

By WM. CAIN, A. M., C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

SEVERAL years ago the writer had occasion to investigate the conditions of stability of a segmental stone bridge, under every probable method of loading. No book in the English language that he knew of, afforded him the means of locating the curve of pressures for an unsymmetrical load (as *e. g.* an engine and train on one side of the bridge), or of determining which was the true curve of pressures out of the indefinite number that could be drawn within the arch ring.

Dr. Hermann Scheffler's German treatise on the "Theory of Arches" solved the problem.

The writer presented this theory to American readers in the October and November, 1874, numbers of this Magazine, together with an account of numerous experiments with wooden arches, in an article entitled "A Practical Theory of Voussoir Arches." As other theories on this subject are still being published and taught, the engineering public are invited to consider *what is the true theory of voussoir arches?*

Some of the points in controversy may be shown, by contrasting Dr. Scheffler's theory with one that has just appeared in the October, 1875, number of this Magazine, by Prof. A. J. Du Bois, who gives there an "Application of the Graphic Method to the Arch." He states that in order that an arch shall be stable, the line of pressures must "lie within the middle third of the arch," and "that is the true pressure curve which approaches nearest the axis, so that the pressure in the most compressed joint edge is a minimum."

Dr. Scheffler asserts that a line of pressures may pass, and generally does pass, outside the middle third of the arch ring and yet the arch be perfectly stable; also that the actual line of pressures in any arch is the one consistent with the minimum horizontal thrust. As a theoretical proof of this last, where vertical external forces alone are considered, we say that the sum of the vertical components equals the weight of the arch, but that the horizontal thrust, which is constant throughout the arch ring, is the minimum that can obtain consistent with stability, for there is no need for a further increase of the horizontal force after it has caused stability. To assert the contrary, would be equivalent to saying, that nature was extravagant with her forces. Why should she, after calling forth sufficient horizontal resistance to insure stability, prodigally increase these molecular stresses? Where would be the limit to this increase? The Rev. Canon Mosely is the author of the "*Principle of least Resistance*," or "*Nature's Economy of Force*," and it inevitably leads us to Dr. Scheffler's conclusions; enabling us to locate the only true and actual curve of pressures in a very simple and direct manner. Numberless illustrations are given in the article before mentioned by the writer, and need not be repeated here. "The true pressure curve" is never by this rule found to be that which approaches nearest the axis; all experiments are against such an assumption.

As to the usual statement, that a line of pressures cannot pass outside the middle third of the arch ring, without the arch tumbling (a fallacy of Rankine and other authors), we have only to remark that experiment undoubtedly and finally disproves it. The conditions of stability for solid and voussoir arches are not necessarily identical. See every experiment recorded in the former article by the writer, in which he says in concluding his remarks upon the experiments: "In every case of *stability* of the arches previously given, it is *impossible* to draw a line of pressures everywhere contained within the inner third of the arch ring. In fact, if such were attempted, it would be found in every case, that such a line of pressures would pass outside the base of the piers or of the arch if used alone." If the reader will construct the line of pressures for any of the experimental arches given by Mr. Bland in his "Experimental Essays of the Principles of Construction in

Arches, Piers, Buttresses, &c.," he will probably reach the same conclusion.

A theory to be of any service to a practical man must agree with experiment. The chemist and physicist found their theories on facts, and revise them in accordance with the latest experiments. The engineer, strange to say, is not so fond of experimenting, but prefers to *assume* a hypothesis and compute the deduction.

This easily accounts for many false theories; as *e. g.*, *supposing* half the weight of two inclined rafters to be acting at their junction; *assuming*, where a beam leans against a wall that the force there is horizontal; *assuming* that the true line of pressures in an arch approaches nearest the axis, or is otherwise than as determined by the principle of the least resistance, or finally in *assuming* that if a line of pressures pass outside the middle third of the arch ring, there as in a solid arch tensile resistances are needed, which, not being supplied by the voussoir arch, insures its destruction. The experiments made by the writer and others go to disprove positively these hypotheses.

Again, many writers divide the *arch* and spandrel into slices by vertical lines of division to get the partial weights and thrusts. As the beds of the ring stones are inclined, except at the crown, this is evidently an incorrect way of procedure. The weight of any number of ring stones with their superincumbent load acting at the centre of gravity, must be combined with the horizontal thrust to get the resultant on the *inclined* bed-joint of the lowest voussoir; not on any supposed vertical joint. In flat arches this error may be small; in full centre arches it is appreciable.

There are usually given by writers empirical formulæ for the depth of arch stones at the crown. With a theory that gives quick and accurate results for uniform or eccentric loads, we should, assuming a depth at crown as given by practice, draw lines of pressure for every variety of loading that is usual and see whether the depth is sufficiently great; assuming that the lines of pressure must not pass nearer the edges than a certain distance, which depends upon the compressibility of the material used. A series of experiments with stone voussoirs is probably the only way in which we can hope to arrive at the exact position of these limiting curves; though existing arches would lead us to infer that these curves are not over one-fifth the depth of the joint from the edge; still, as bridges are subject to shocks, it would seem that one-fourth or one-third depth of joint could be assumed with safety.

There is scarcely any subject about which so many different theories have been from time to time advanced as this one of arches. If experiment is to be the criterion, which theory best stands the test?

COUPLED LOCOMOTIVES.

From "The Engineer."

A WIDE diversity of opinion still exists among locomotive superintendents as to the relative merits of coupled and single locomotives. Keen discussions on the subject were carried on years ago in our pages; and it would not be difficult to find a score of combatants ready to enter the lists again and fight over this subject. A very eminent locomotive builder was once shown a very strange looking engine which he was told did very good work. He said he was not surprised to hear it, for "anything would do for a locomotive." The statement was, of course, exaggerated; it was meant as a somewhat bitter jest, and yet it was not wholly untrue. As a matter of fact the locomotive appears to possess an astounding power of adapting itself to circumstances; and so long as good material and workmanship are present, the design of an engine appears to exert very little influence on either its economy or utility. We hear it stated, of course, now and then that only engines of a certain design can do a particular work, but such

assertions must always be taken with a grain of salt. Heavy goods engines with small drivers have ere now been beaten on their own ground by express passenger engines which have hauled as great a load at higher speed and with no excessive consumption of fuel; and goods engines, on the other hand, have before now in the hands of enterprising drivers been on an emergency made to keep perfect time with express trains. It is no doubt to this wonderful power of adapting itself to circumstances possessed by the locomotive that we must look for an explanation of the fact that so many points of apparently vital importance connected with its design and construction still remain entirely unsettled, and ready at any moment to supply matter for a warm dispute between railway men.

As regards the question concerning which this article is written, it may be stated that little has been done of late years to take it out of the region of discussion based on pure theory. While on some lines the coupled engine grows in favor, on others the tendency is to revert to the single engine. There is scarcely a line in Great Britain in which coupled passenger engines are not used more or less. But it has been found in certain cases that single engines can be made to take the place of the coupled engines used for years in conducting a given traffic, and with advantage. There is really no inconsistency in this; it is well known that single engines always run more freely and with less internal resistance, if we may use the words, than coupled engines. On one great line we are assured that the saving in fuel effected by using single instead of coupled engines amounts to approximately 3 lb. of coal per mile, or to something like 10 per cent. of the entire passenger engine coal bill. If this be the case it is not wonderful that single engines have been substituted with advantage for coupled engines. How it is possible to make the substitution is easily explained. The solution of the problem lies in the fact that, with steel rails and a strong road it is possible to load a single pair of wheels sufficiently to secure ample adhesion, so long as the diameter of the wheel does not get below 6 ft. 6 in., and the cylinders do not exceed 17 by 24. Steel rails have enabled us to carry as much as 16 tons with a single pair of drivers; and a very simple calculation will show that in the case of such an engine as we have named an averaged pressure of at least 60 lb. on the square inch throughout the whole stroke would be required to make the wheels slip if the adhesion was but one-sixth of the insistant weight. It may be argued that one-sixth is not enough. The answer lies in the fact that it is found to suffice, and a great many locomotives are now running most successfuly which ought to slip their wheels whenever the average effective cylinder pressure exceeds 60 lb. on the square inch, and we are led to the conclusion either that the pressure does not exceed this, or that the coefficient of adhesion is much greater than one-sixth, for the engines never slip enough to prevent them from keeping time with very heavy trains. It is worth considering again whether coupling an engine confers all the benefits usually supposed to result from the practice. When rails are really in bad condition four wheels seem to possess no more adhesion than two, and we are disposed to regard the coupling of passenger engines, properly so called, as of very little real advantage. The conditions under which coupling is and is not necessary may be very easily defined. When the diameter of the driving wheels, the load on them, the capacities of the cylinders, and the boiler power, are properly proportioned to each other, a single pair of drivers will give all the adhesion requisite for even heavy passenger traffic in ordinary weather. The coupling of such an engine would give her a trifling advantage in bad weather—probably an advantage not worth the extra consumption of coal entailed by coupling. This proposition will not apply generally to engines with driving wheels less than 6 ft. 6 in. diameter.

When a less diameter than this is used, it will be found that with loads of less than 16 tons on a single pair of drivers, the engine will not have adhesion enough in any weather, unless the cylinders are too small and the boiler pressure too low, and such an engine should be four-coupled. When we get to driving wheels at and below 5 ft. in diameter, with 17 in. cylinders, or there-

abouts, then the engine should be coupled all round.

If these propositions are accepted as being approximately accurate, then no difficulty will be met with in deciding whether an engine ought or ought not to be coupled. A given diameter of cylinder may be taken always—within reasonable limits—to represent a given weight of engine, available for adhesion; we may therefore dismiss, in practice, the size of the cylinder altogether, and decide whether an engine should or should not be coupled by the diameter of the driving wheels. Experience then goes to show that wheels over 6 ft. 6 in. in diameter need never be coupled, while wheels under 5 ft. 6 in. diameter should always be coupled; between 5 ft. 6 in. and 6 ft. 6 in. will exist a species of debatable land. It will depend on various circumstances whether it will be best to couple or not wheels of 5 ft. 9 in., 6 ft., or 6 ft. 3 in. If the road is good and tolerably level, and the climate dry, then coupling may better be dispensed with; if, on the contrary, the road is bad and yielding, so that the rail does not stand well up to the driving wheel, but by deflecting tends to permit a redistribution of the load, the leading and trailing wheels taking more than their due weight, and the climate wet, then coupling may be resorted to with advantage. It must be understood that we have been considering the case only of engines making fairly long runs, and that we do not refer at all to such exceptional traffic as that of our metropolitan railways. In main line work it is not necessary to get a train away quickly, and a judicious driver, with the aid of a little sand, will easily get his train into motion without slipping whether his wheels are coupled or not, always provided that they are not so small that they ought to be coupled.

We are quite aware of the fact that exception may easily be taken to what we have advanced, but we believe, nevertheless, that it is in the main consistent with the best modern practice. An idea has been floating about for some time that the coupling question ought to be settled by the diameters of the driving wheels of a locomotive, and all that we have endeavored to do is to put this idea into something like a tangible shape. It may be argued that it is rash to use the diameter of a wheel as a standard by which to settle such a question, because engines exist with wheels much less than the minimum diameter we have named which do not require to be coupled. The answer is that they do not need it because they have small cylinder capacity in proportion to the size of the wheels. They are, in a word, little engines; but such locomotives are not used for working main line traffic, and it is to such traffic and such only that we have referred. The use of steel rails, we may in conclusion point out, has certainly reduced the necessity for coupling, by enabling locomotive superintendents to put loads on their driving wheel, at which an older school of engineers would stand aghast. Whether in the long run it is better, for the interests of share-holders, to use single drivers carrying these enormous loads, or coupled engines carrying much less, we shall not pretend to decide, because questions concerning the expense of maintaining the road are involved, with which just at the moment we have nothing to do. We believe that a single engine properly proportioned will do her work perfectly, and with less coal and repairs than a coupled engine on the same job, so long as the work is not too much for a 6 ft. 6 in. wheel. Whether it is or is not judicious to attempt to run fast passenger and express traffic with a wheel much smaller than this is a matter on which there is very little difference of opinion. We venture to think that the great majority of locomotive superintendents in Great Britain will hold with us that a much smaller wheel than this is not suitable for engines which have to make an average time of forty-five miles an hour, or thereabouts.

THE United States Treasury Department has just decided—says the *American Manufacturer*—that the materials of boiler bottom, composed of iron, tin and lead, similar to the terne plate of commerce, loses its identity as terne plate when moulded into shape for use, and is dutiable at thirty-five per cent. *ad valorem*.

THE CONSTRUCTION OF ELLIPSES.

By JOHN H. GILL, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In all "pocket books," manuals, and instructions on Geometrical Drawing, the Ellipse fares badly, and its beautiful curve is usually degraded to the oval, a combination of circular arcs, or is made to depend upon a string.

By your leave I will give some simple directions for finding any number of points in a given ellipse, without the use of analytical formulæ, and by which any ellipse between its extremes—a right line and a circle—may be accurately drawn, or any *part* thereof, independently of the other parts

First, however, I will describe, by a rough drawing, a simple machine I have contrived for drawing ellipses. It consists of a frame A, A′ (Fig. 1), and the

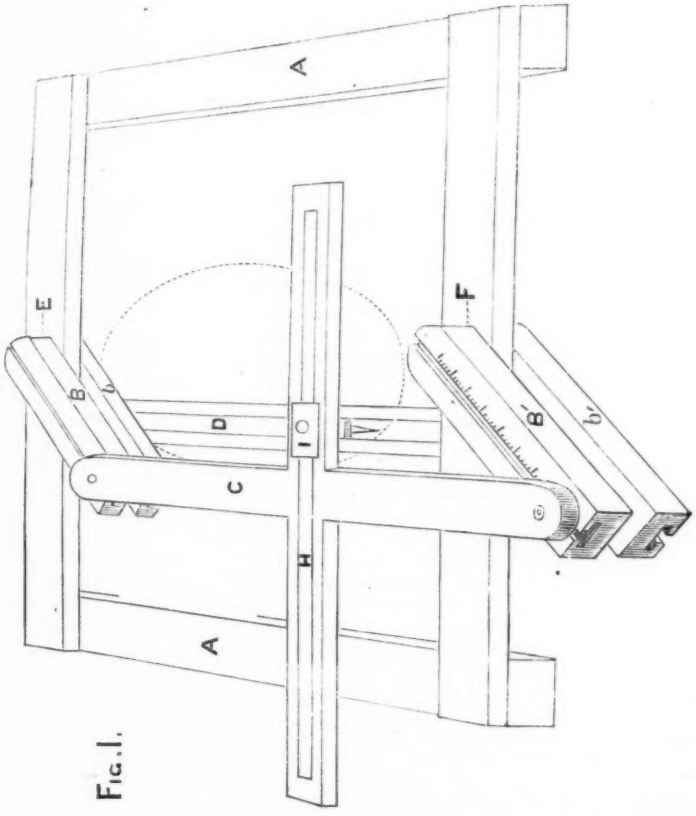

FIG. 1.

two pairs of cranks B b and B′ b', having grooves in them as shown, in which work sliding wristpins, which may be secured at any point on the cranks cor-

responding, in distance from their centers, to the semi-major, and semi-minor axes of the required ellipse. Upon these wristpins work the connecting bars C and D, and these are of such length (E F) as to secure a perfect parallelism between the two sets of cranks. C has a slotted bar, H, at right angles to C at its middle point, and D is slotted in the direction of its length. A cross-shaped pencil holder I, slides in both these slots simultaneously. To use the machine, the wristpins of C are set on the cranks B, B′ (by a scale marked on them) at a distance from their centers equal to the semi-major axis of the proposed ellipse, and those of D are set on b, b' at a distance equal to its semi-minor axis. A pencil being placed in the holder, and gently pressed down by a spring or elastic cord; the instrument set over a sheet of paper, and a revolution given the cranks, traces an accurate ellipse. The ratio of the axes may be made anything from unity to infinity. In the first case the wristpins of C and D would be at equal distances from the crank centers, and the resulting curve would be a circle. In the second case one pair of wristpins would be *at* the crank centers, and a right line would be the result. So much for the mechanical method which requires no demonstration, though the following method of geometrical construction, of which the mechanical is an outgrowth, will demonstrate it.

Draw through the proposed center, O, (Fig. 2) of the ellipse two lines perpendicular to each other. Set off A A′ equal to the major axis, and B B′ equal to the minor axis, and upon them as diameters describe the circles shown. Take *any* point P, on the outer circle, and draw the radius P O, cutting the smaller circle in P′. Through P draw a line parallel to B B′, and through P′ draw a line parallel to A A′. The point of intersection, E, of these lines is a point of the ellipse. For P E : P′ P″ (or E E′) : : P O : P′ O, which expresses the relation between the ordinate of an ellipse, and the corresponding ordinate of the circle described on its major axis. Therefore (Davis Am. Geom. Ellipse, Prop. IV.) E is a point in the required ellipse. In the same manner any number of points may be found.

FIG. 2

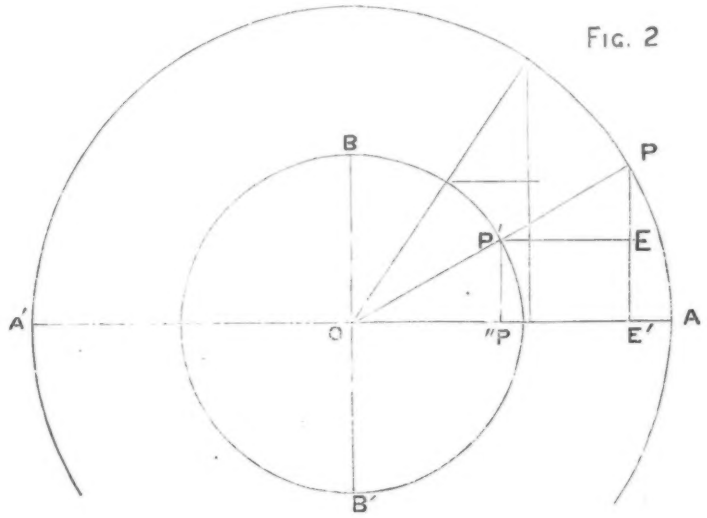

Table for constructing any ellipse or circle, or parts thereof, whether the centers or foci are upon the paper or not:

(*See Table following page.*)

Example of use of Table.—Suppose it is required to construct an ellipse whose

	1		2		3		4		5		6		7		8		9	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
5°	.996	.085	1.992	.174	2.988	.261	3.984	.348	4.980	.435	5.976	.522	6.972	.609	7.968	.696	8.964	.783
10°	.984	.173	1.968	.346	2.952	.519	3.936	.692	4.920	.865	5.904	1.038	6.888	1.211	7.872	1.384	8.856	1.557
15°	.955	.258	1.930	.516	2.895	.774	3.860	1.032	4.825	1.290	5.790	1.548	6.755	1.806	7.720	2.064	8.685	2.322
20°	.939	.342	1.878	.684	2.817	1.026	3.756	1.368	4.695	1.710	5.634	2.052	6.573	2.394	7.512	2.736	8.451	3.078
25°	.906	.422	1.812	.844	2.718	1.266	3.624	1.688	4.530	2.110	5.436	2.532	6.342	2.954	7.248	3.376	8.154	3.798
30°	.866	.500	1.732	1.000	2.598	1.500	3.464	2.000	4.330	2.500	5.196	3.000	6.062	3.500	6.928	4.000	7.794	4.500
35°	.819	.573	1.638	1.146	2.457	1.719	3.276	2.292	4.095	2.865	4.914	3.438	5.733	4.011	6.552	4.584	7.371	5.157
40°	.766	.642	1.532	1.284	2.298	1.926	3.064	2.568	3.830	3.210	4.596	3.852	5.362	4.494	6.128	5.136	6.894	5.778
45°	.707	.707	1.414	1.414	2.121	2.121	2.828	2.828	3.535	3.535	4.242	4.242	4.949	4.949	5.656	5.656	6.363	6.363
50°	.642	.766	1.284	1.532	1.926	2.298	2.568	3.064	3.210	3.830	3.852	4.596	4.494	5.362	5.136	6.128	5.778	6.894
55°	.573	.819	1.146	1.638	1.719	2.457	2.292	3.276	2.865	4.095	3.438	4.914	4.011	5.733	4.584	6.552	5.157	7.371
60°	.500	.866	1.000	1.732	1.500	2.598	2.000	3.464	2.500	4.330	3.000	5.196	3.500	6.062	4.000	6.928	4.500	7.794
65°	.422	.906	.844	1.812	1.266	2.718	1.688	3.624	2.110	4.530	2.532	5.436	2.945	6.342	3.376	7.248	3.798	8.154
70°	.342	.939	.684	1.878	1.026	2.817	1.368	3.756	1.710	4.695	2.052	5.634	2.394	6.573	2.736	7.512	2.078	8.451
75°	.258	.965	.516	1.930	.774	2.895	1.032	3.860	1.290	4.825	1.548	5.790	1.806	6.755	2.064	7.720	2.322	8.685
80°	.173	.984	.346	1.968	.519	2.952	.692	3.936	.865	4.920	1.038	5.904	1.211	6.888	1.384	7.872	1.557	8.856
85°	.087	.996	.174	1.992	.261	2.988	.348	3.984	.435	4.980	.522	5.976	.609	6.972	.696	7.968	.783	8.964
90°	.000	1.000	.000	2.000	.000	3.000	.000	4.000	.000	5.000	.000	6.000	.000	7.000	.000	8.000	.000	9.000

major axis is 48, and minor axis 12. The semi-axes are 24 and 6.

Under 2 and x are found the abscissas
1.992, 1.968, 1.930, 1.878, &c.
Multiplied by 10, we have for 20,
19.92, 19.68, 19.30, 18.78, &c.
Under 4 and x we have
3.984, 3.936, 3.860, 3.756

Giving for 24,
23.904, 23.616, 23,160, 22.536
which are set off (Fig. 3) on a line rep-

FIG. 3.

resenting the major axis, from a point representing the center of the ellipse; or, if this point is not on the paper, their complements with respect to 24 may be taken, and these distances set off in a contrary direction, from the *vertex* of the

ellipse; at the points so found erect perpendiculars. Next under 6 and under y we find .522, 1.038, 1.548, 2.052, &c., as ordinates, and these are to be set off on the corresponding perpendiculars, and will give points of the ellipse.

For circles the table is used in the same way, the axis being equal the values of x and y will be found in adjacent columns under the same bracket.

The first column on the right gives the angle which the radius to the point, represented by the coordinates on that line, makes with the major axis.

ON THE ALLEGED EXPANSION IN VOLUME OF VARIOUS SUBSTANCES IN PASSING BY REFRIGERATION FROM THE STATE OF LIQUID FUSION TO THAT OF SOLIDIFICATION.

By ROBERT MALLET, F. R. S., &c.

Proceedings of the Royal Society.

The fact that water expands in becoming ice, and that the latter thus floats upon the water, can scarcely have escaped the observation or inference of the acute intellects of a remote antiquity. Its conditions, when more carefully examined in modern times, pointed out the strange and, as it has been called, anomalous fact that water can be cooled 7° or 8° below its freezing-point without becoming solid, and that between its maximum density at about 39° Fahr. and its freezing-point at 32° Fahr., or within the narrow range of 7° Fahr., it expands in the large ratio of 915 : 1000

Standing thus alone amongst observed phenomena in nature, it seems to have suggested to many experimenters the question whether other bodies when liquefied by heat might not also expand when becoming solid by refrigeration. I have not attempted to trace with minuteness the history of past inquiry upon this subject, many loose uncertain statements as to which have for at least a century continued to perplex scientific literature. Réaumur appears to have been the first who gave currency to the statement that cast iron, bismuth, and antimony all expand in consolidating. The like fact has been alleged or left to be inferred with respect to the following substances by the authorities named :

Silver, Persoz.
Copper, Karsten.
Mercury and Gold, as inferred by Nasmyth and Carpenter.
Iron and Furnace-slags, by experiment of Heunter and Snelus, as quoted by Nasmyth and Carpenter.

But of this list the only body, in addition to water, that really appears proved to expand in consolidating is bismuth ; and even this the author cannot affirm upon the basis of his own experiments, but accepts the fact, at least provisionally, as true upon the uncontradicted statements of many chemical authors, and upon the positive assurance which he is permitted to mention by Dr. John Tyndall that he is satisfied of its truth. With respect to all the others, it is the object of this communication to show that the evidence in support of the alleged fact of expansion by refrigeration is illusory and insufficient, and to offer with respect to cast iron, and also with respect to iron furnace-slags, experimental proof of the untruth of the statement.

Certain connected but only collateral facts, having regard to so-called anomalous changes of volume due to temperature, will not be referred to here—such, for example, as the anomalous expansion of Rose's fusible metal, which expands progressively, like other bodies, till it attains the temperature of 111° ; it then contracts rapidly by added heat to 150°, when it is densest (Graham's 'Elements,' vol. i., and Gmelin's 'Handbook'), the circumstances being here probably due to the successive segregation in the mass of alloys differing from each other in

constitution, dilatability, and fusing-points. Or, again, the facts observed with respect to the expansion or contraction in volume shown by certain salts when crystallizing from their solutions, the whole of the conditions as to which have not been as yet made quite clear. The statement that antimony expands in consolidating, as made by Réaumur, has been negatived by Marx. The like statement with respect to silver and copper appears to rest on no better foundation than the observation as stated by Persoz, "that pieces of solid silver float, upon the melted metal, showing that silver expands in sodidifying like water." As to gold, there appears no authority whatever for its expansion on consolidation. Mr. Nasmyth has included it in his catalogue merely on the vague inference that, like silver and copper, it "exhibits surface-converging currents in the melting-pot like those depicted by him for molten iron," which, as we shall see further on, affords no grounds for conclusion on the matter. Reaumur's statement with respect to cast iron appears to have rested upon nothing more than the fact that he had observed certain pieces of cold cast iron to float upon cast iron while in fusion. Until lately this subject generally attracted but little attention, for it had very few, and these mere technical, applications; and to the higher physicist they presented but little interest, because the loosely stated facts, even if accredited, did not in the slightest degree tend to elucidate or explain the remarkable and perhaps still isolated facts as to water and ice. Accordingly, with little or no examination, the statements given for facts by the older authorities have been accepted and become current from book to book of authors up to the present day, as when Dr. T. Thompson says of cast iron that "it contracts considerably when it comes into fusion," or that of Kerl, that cast "iron occupies a smaller space after cooling than when in the liquid state; it contracts in such a manner that, at the commencement of its solidification, it first expands so as to be able to fill up the smallest depressions and cavities of a mould, but after solidifying it contracts"—a loosely worded statement, which in various forms may be found in a great number of authors upon metallurgy and technology. So likewise the statement often repeated, that the value of antimony in type-metal consists in its causing the latter to expand upon consolidation and so perfectly fill the matrix, is presented, so far as the author's reading goes, without the slightest experimental proof of its truth, and appears to rest simply upon Réaumur's statement with respect to antimony itself, which, as already mentioned, has been controverted by Marx. This subject, however, has now assumed greater importance, since it has recently been made by Messrs. Nasmyth and Carpenter the foundation upon which they rest their theory of lunar volcanic action, as presented to us by the surface of our satellite; and the object of the present communication is to show that, as regards the two most pertinent of the substances adduced by these authors, viz. cast iron and iron furnace-slag, the facts entirely fail in support of their theory.

First, then, as to cast iron. It is not a fact that all cast iron in the solid state will float upon all cast iron in liquid fusion, though such might be inferred from the broad and loose statements of authors. Even in the limited form in which the statement is made by Nasmyth and Carpenter—viz. "that when a mass of solid cast iron is dropped into a pot of molten iron of identical quality the solid is found to float persistently upon the molten metal, so persistently that when it is intentionally thrust to the bottom of the pot it rises again the moment the submerging agency is withdrawn" ('The Moon,' p. 21)—is not quite exact.

It is a fact that certain pieces of cast iron in the solid and cold state will float on certain descriptions of cast iron in liquid fusion; but whether the solid pieces shall float or not float in any given case is dependent at least upon the following conditions, and probably upon others not yet ascertained:

1st. Upon the relative specific gravities of the solid and of the fused cast iron both referred to the temperature of the atmosphere. Under the commercial name of cast iron is comprehended a wide range of compounds of iron with other substances, which compounds differ greatly in their physical as well as

their chemical qualities, and have a range of specific gravity of from nearly 7.7700 for the whitest, most rigid, and dense, down to little more than 6.300 for those which are darkest, softest, and most porous. The total dilatation at the fusing-point of the denser cast irons is known to be somewhat greater than that of the less dense; but as the increase in volume may not be sufficient to equalize the specific gravity of a very dense iron when in fusion with that of a very light iron when cold, so it is obvious that a piece of cold cast iron might be so selected in reference to its specific gravity, as referred to that of another sort of cast iron in fusion, that the former should either sink or swim upon the latter by mere buoyancy, were that free to act alone.

2d. Assuming the cold and the molten cast iron originally identical in qualities, whether a piece of the former shall float or not float upon the latter depends not only upon buoyancy as above, but also upon the form of the piece of cold metal—that is to say, on the relation, all other things being the same, that subsists between its volume and its surface.

3d. The force, whatever be its nature, which keeps the piece of cold cast iron floating is of sufficient energy to overcome a considerable want of buoyancy in the cold iron under certain conditions, so that it may float upon molten cast iron whose specific gravity, as such, is much less than that of the colder iron which floats upon it. Messrs. Nasmyth and Carpenter assume, without any sufficient proof, that solid cast iron floats on liquid iron of the same quality in virtue of buoyancy alone, and proceed to state that "inevitable inference from this is that in the case of cast iron the solid is specifically lighter than the molten, and therefore that, in passing from the molten to the solid condition, this substance undergoes expansion in bulk" ('The Moon," pp. 20, 21).

I proceed to prove that this view is altogether contrary to fact. The determination of the specific gravity of cast iron in its molten condition is a problem of considerable difficulty, and can only be solved by indirect means; we cannot ascertain its specific gravity by any of the methods ordinarily employed, nor can any areometric method be used, as any hydrometer or solid of known specific gravity at common temperatures, when dipped into liquid cast iron, changes its volume as well as gets incrusted with adherent cast iron or its oxydes, &c. By an indirect method, and by operating upon a sufficiently large scale to eliminate certain sources of error, the specific gravity of molten cast iron may, however, be approximately ascertained with considerable accuracy. The method adopted by the author was as follows:—A conical vessel, was formed of wrought-iron plate by welding up only, the walls of the vessel being about $\frac{1}{2}$ in. in thickness. It was perfectly smooth in the inside, and the plane of the lip of the open neck was carefully made parallel to the plane of the base. This vessel weighed, when empty, 184.75 lbs. avoirdupois. The orifice of the neck being levelled as the vessel stood upon the platform of the weighing-apparatus, it was filled up to the exact level of the neck with water at a temperature of 60°.5 Fahr., and again weighed. Deducting the weight of the empty vessel, the weight of its contents of water was found to be 94.15 lbs. avoirdupois. From the known volume and weight of the imperial gallon of distilled water, the capacity of the vessel was therefore at 60° Fahr.=2605.5 cubic inches. As a check upon the results, both as to weight and capacity, the water was measured into the vessel from accurate glass standards of volume. The water employed was that from the well at Messrs. Maudslay, Sons, and Field's Engine Works, Lambeth, where these experiments were conducted, and to whose liberality the author owes the means of having performed them. The specific gravity of this well-water did not very materially exceed that of distilled water, being about 1.0004; but if we apply the necessary correction, the weight of the contents of the iron vessel of distilled water at 60° Fahr. is 94.112 lbs. avoirdupois. The vessel being emptied, carefully dried and warmed, and stood upon a hard rammed bed of dry sand with its neck perfectly level as before, was now filled perfectly level to the brim with molten cast iron. As the temperature of the vessel itself rapidly rose by contact with the large mass of molten

iron within it, and by its dilatation had its capacity enlarged, so the top surface of the liquid cast iron within it rapidly sank, fresh additions of molten iron being constantly made to maintain its top surface level with the brim. This was continued until the whole of the exterior of the vessel was seen to have arrived at a clear yellow heat, beyond which no increase to its temperature took place. At about twenty minutes after the molten iron was first poured into the vessel, this point was reached, the feeding in of additional iron being discontinued a few minutes previously. The whole being left to cool for three days, the vessel full of the now cold and solid cast iron was again weighed; on deducting, as before, the weight of the empty vessel, the weight of the cast iron which filled it was found to be 645.75 lbs., which, with certain corrections to be yet noticed, was the weight of cast iron which, when in the molten state, was equal to the capacity of the conical iron vessel in its expanded state due to its exalted temperature. We have now to determine what was the capacity of the vessel in this expanded state. The temperature at which cast iron melts may be admitted as about 2400° Fahr.; but as iron tapped from the cupola is always above its melting-point, we may admit that it was poured into the vessel at 2600° or 2700° Fahr., the surplus heat in the cast iron, whose mass was about four times that of the wrought-iron vessel which contained it, being given off in the first instance to heat the latter. The temperature at which wrought iron presents to the eye a clear yellow visible in daylight may, in accordance with the views of most physicists, be taken as between the fusing-points of silver and of gold, or at 2000° Fahr. The mean coefficient of linear dilatatian for 1° Fahr. of wrought iron has been determined between the limits of zero and 212° by Laplace, Smeaton, Troughton, and Dulong, the average of the four being 0.00000699 for 1° Fahr.; and this is certainly below the truth for the whole range of temperature up to fusion, as the rate of expansion of all fusible bodies appears to increase with the temperature. Rinmann has determined the linear dilatation of a bar of wrought iron, when raised from 60° Fahr. to a white or welding heat, to be $\frac{1}{80}$ of its length, or .0125; and taking the total range of temperature here at 2400°, we have a mean coefficient of linear dilatation =0.0000052 for 1° Fahr. This is a still smaller coefficient than the preceding; the author has, however, preferred to adopt it in order to avoid any pretense to exaggerate in his own favor the results arrived at. Applying, then, Rinmann's coefficient to the dimensions of the cone at 60° Fahr., and to its temperature (2000° Fahr.) when at the maximum, we are enabled to deduce the true capacity of the cone when expanded to the utmost and filled with molten iron, viz. =2691.77 cubic inches. The iron conical vessel was now cut off by a circular cut at the base and another up and down the side of the cone, and separated from the conical mass of iron that had filled it; the interior surface of the iron vessel was found in several places about the lower part of the cone in perfect contact with that of the cast iron which had filled it; but in other portions very slightly distant from it, as judged by the sound of a hammer upon the sides of the vessel before it was cut off. The cast iron was not adherent to the vessel anywhere. The cast iron cone being thus laid bare, had a V-shaped piece cut out of it (in the "slotting" machine), by two planes, each passing through the axis and meeting at an angle of about 60°. The conical mass proved perfectly sound and free from cavities or blow-holes anywhere, except very near the summit or neck, where there was found to be a hollow or cavity accidentally left during the feeding (as above described). By measurement the volume of this cavity was found to be= 5.5 cubic inches; assuming this cavity filled with iron of the same quality as the cone, the weight of the latter would be increased by 1.43 lb., making thus the corrected total weight of the solid cone of cast iron =647.18 lbs. From the wedge-shaped piece cut out from the cone at half its altitude, and about halfway between the axis and circumference of the sector, a piece was cut out, the specific gravity of which, taken by the usual methods, proved to be 7.170, which may be taken as the mean specific gravity at 57° Fahr. of the whole of the cast iron that filled the cone. Reverting now to the conical vessel which con-

tained at 60° Fahr. 94.112 lbs. of distilled water, its capacity being 2605.5 cubic inches: this capacity was enlarged by expansion when filled with molten iron to 2691.777 cubic inches, so that the conical vessel when cold, if it had had the same capacity as when filled with liquid iron, would have contained 97.224 lbs. of distilled water. We have now all the elements necessary for calculating the specific gravity of the cast iron which filled the cone in its molten state, because we have the actual weights of equal volumes of distilled water and of molten iron. The final results, then, are, that whereas the cast iron which filled the cone had when cold (57° Fahr. a specific gravity, as above given, = 7.170, the same cast iron in its molten state, as poured into the cone, had a specific gravity of only 6.650—in this case thus proving that the density of cast iron in its liquid state is not greater but, on the contrary, very much less than that of the same cast iron at the temperature of the atmosphere. The quality of cast iron employed in this experiment was the fine, bright, close-grained metal usually employed by Messrs. Maudslay, Sons, and Field for their engine-castings, and consisted of

½ Best scrap*—all by weight.
¼ Gartsherrie, } Scotch,
¼ Coltness, }

It may be taken as a typical or medium example of all good gray cast irons. I have not been enabled to repeat this experiment with the white, rigid, and crystalline cast irons, such as are employed for projectiles and other purposes; but as it is a recognized fact amongst iron-founders that these irons expand in the range of temperature between solidity and liquidity *much more* than do gray irons, so we may justifiably conclude that the decrease of specific gravity by fusion of these hard cast irons would be in even a greater ratio than that shown by the above experiment on gray iron; and generally the author feels himself justified in concluding that it is not true that *any* cast iron is denser in the fused than in the solid state. Cold cast iron, therefore, does not float upon liquid cast iron of the same quality by reason of its buoyancy, but in virtue of some force which tends to keep it upon the surface of the molten metal in opposition to a very considerable want of buoyancy or tendency to sink by greater density on the part of the solid iron, which is, by the preceding results, $\frac{1}{13.8}$ of its weight, whatever that may be, and is probably even greater than this in the case of hard white cast irons. The author's chief object has been thus far rather to prove that the cause assigned by the writers already mentioned is *not* the true cause of the floating of solid upon liquid cast iron of the same quality.

What *is* the nature of the force which produces this curious phenomenon and often in direct opposition to gravity, is a different and a much more delicate and difficult inquiry, which he must leave to physicists to fully investigate. The following experiments, however, may be placed on record as tending to afford some little dawn of light upon the subject.

The following experiments were made with pieces of iron cast from cast iron of the same quality as that which filled the experimental cone, placed upon or immersed in molten cast iron of like quality with themselves, so far as such can be secured by "tapping" at nearly the same time from the same cupola charged with the same materials.

Before proceeding to describe these, it will be necessary to deduce from the cone experiment a mean coefficient of total cubic dilatation for the whole range between 60° and 2400° Fahr. for the gray cast iron employed in these experiments. The total dilatation was, as we have seen, such as reduced the specific gravity of the cast iron when cold (=7.17) to 6.65 when in fusion. The cubic dilatation was therefore in the inverse ratio of these numbers, or as 1000 : 1078; and dividing this increase in volume by 2340° Fahr., the total range of temperature, we obtaian for the mean coefficient of cubic dilatation of this gray cast iron for 1° Fahr. = 0.0000333, or approximately for its mean coefficient of linear dilatation $\frac{0.0000333}{3} = 0.0000111$.

These coefficients are nearly double those obtained by Roy and by Lavoisier for a range of temperature of 180° Fahr.

*Disused and broken-up castings.

viz. between 32° and 212°, which is quite what we should expect, as the coefficient of dilatation in all bodies increases with the temperature.

We have seen from what precedes that two forces at least are concerned in the phenomenon of cold cast iron floating upon the same when liquid, viz :—

A. *Buoyancy* or its opposite, dependent upon the relation between the actual specific gravity of the cold metal and that of the liquid metal upon which it is placed, and whose absolute power for any given difference of specific gravity depends upon the *volume* only of the floating mass.

B. A *repulsive force* of some kind tending to repel the surfaces in contact of the hot and cold metals. Whatever be the form of the floating solid, this repulsive force can only be effected in producing flotation upon such surfaces of the floating solid as are parallel to the surface of the liquid metal, or at least so circumstanced that repulsions upon one surface, or part of a surface, are not equilibrated and nullified by repulsions upon others in the opposite direction. Thus if a parallelopiped float with one of its surfaces parallel to that of the liquid metal, the repulsions upon its immersed vertical sides, taken two and two respectively, are in opposite directions, and therefore nullified, and the bottom or horizontal surface is alone effective in producing flotation. So also if a cylinder float with its axis horizontal, the ends are ineffective, as is also all that portion of the cylindric surface immersed which is above the level of the horizontal diameter of the cylinder.

These preliminary explanations will enable us better to interpret the following experiments :

Experiment 1. An irregular piece, believed to be of hard and dense cast iron, and also a ball of about 2½ in. diameter, believed to be of close-grained gray iron : both sunk to the bottom when thrown into the ladle of liquid iron, and remained for some time at the bottom ; both, however, reappeared upon the surface when they had acquired a temperature sufficient to have fused off portions of their respective masses.

In every fresh-lined ladle of liquid cast iron there are circumferential ascending and central descending currents in the metal, produced by the gases evolved from the lining, as hereafter fully explained. It is no doubt chiefly to these ascending currents that the heated ball in Experiment 1 owed its ascent to the surface ; for if the heating took place in perfectly motionless cast iron, there seems no reason why the place of the sunken ball should change up to the moment of complete fusion.

Experiment 2. Two parallelopipeds, each $2'' \times 2'' \times 6''$, were cast of close gray iron ; one of these was placed cold upon the surface of a large ladle of liquid iron of like quality ; the other was heated as hot as it would bear without distortion, viz. to nearly a bright yellow heat, in a forge-fire, and then placed upon the surface of the liquid metal. Both pieces floated, and, as nearly as could be judged, both to the same height above the liquid, namely 0.1808 in. The volume of the cold piece being 24 cubic inches, the ratio of the immersed to the emergent portions was 9.6 to 1, the effective surface upon which the repulsive force could act in producing flotation being 12 sq. in. Assuming that the heated piece has been raised from 60° Fahr. (the temperature of the cold piece) to 2000° Fahr., and applying the mean coefficient of cubic dilatation as above given to this range of temperature, viz. 2000° − 60° = 1940° Fahr., we find that its volume was enlarged to 24.75 cubic inches, or $= \frac{1}{24}$ of the volume when cold ; and taking the specific gravity of the cold piece to have been 7.17 (see *ante*), that of the hot piece would be reduced to 7.10 ; the effective repellent surface was slightly enlarged in the hot piece, and the immersed volume was to the emergent volume as 9.66 : 1. The buoyancy of the heated piece had been increased, or, more correctly, its *negative* buoyancy had been decreased, as compared with that of the cold piece, but yet it has sunk deeper into the liquid iron in proportion to their respective volumes. We may therefore be justified in concluding that the repellent force which kept both pieces afloat is diminished in energy in some proportion as the difference in temperature between the liquid metal and the piece floating upon it is diminished, and that where the liquid and the floating pieces are alike in quality of metal, both the negative buoyancy and the re-

pellent force must both disappear at the instant that the floating piece itself becomes liquid by heat abstracted from the molten metal.

Experiment 3. Two cylindric pieces of the same gray cast iron and of the same diameter (=2.375″) were gently placed with their axes horizontal upon the surface of the molten iron, the one being at 60° Fahr., the other at about 300° Fahr.; they both floated with a segment of the cylinder whose versed sine was 0.31 in. emergent. The volume of either cylinder was 22.15 cubic inches, and the emergent was to the immersed volume as 1 : 8.4. The effective repellent surface in each case (or cylindric surface below the horizontal diameter) was 18.65 sq. in.; but if we suppose, as in fact we have done, that the repellent force, whatever be its nature, acts everywhere perpendicularly to surfaces of contact of the solid and liquid, then the effective repellent surface here is only the difference between the immersed surfaces of the cylinder below and above the horizontal diameter, or 9.3 sq. in. From this we may perhaps conclude that the repellent force is mainly dependent upon the extreme upper parts of the range of temperature between the liquid and the cold body, inasmuch as an augmentation in temperature of the latter of 300°, or about $\frac{1}{8}$ of the entire range between solidity and fusion of the cast iron, produces no very sensible alteration in the tendency to float of the pieces.

Experiment 4. Three circular disks of the same gray cast iron, each of 6″ diam. by 0.375″ in thickness, were provided each with a slender iron wire eye, cast into the centre of one surface, so that by a hooked wire they could be gently laid upon the surface of the liquid iron of their own quality. The lower surface and edge of one disk were left as it came clean from the sand, those of another were rusted by wetting with solution of sal-ammoniac, and those of the third were ground smooth and polished by the grindstone. When the three disks were in succession laid upon the surface of the molten iron, they all floated alike as nearly as could be judged, each sinking to one half the thickness of the disk, so that the immersed was to the emergent volume in the ratio of equality. We may conclude from this that the condition of the metallic surface of the solid cast iron has no material influence upon its flotation.

Experiment 5. Two circular disks, provided with eyes as in Experiment 4, were prepared, the one being 6 in. in diam. by 0.375 in thickness, and the other 3 in. in diam. by 1.5 in. in thickness. The respective volumes of these two disks are the same, but the circular flat surfaces respectively are as 4 to 1. The surfaces of the two disks being as they came from the sand-mould, they were placed gently upon the surface of the molten iron: both floated with the same portion in altitude emergent. The larger and thin disk had, as stated in Experiment 4, its emergent and immersed volumes in the ratio of equality [or the emergent was to the whole volume as 1 : 2]. In the smaller and thicker disk, the emergent volume was to the immersed volume as 1 to 7. [Or the emergent volume was to total volume as 1 : 8; but 2 : 8 :: 1 : 4, or the emergent volumes are to the total volumes in each case respectively proportionate to the lower or repellent surfaces of the disk.]

Now the effective repellent surfaces are here those of the lower circles of the respective disks, and these surfaces are to each other in the ratio of 1 (the larger) to $\frac{1}{4}$. Whatever be the nature, therefore, of the repellent force, it seems to be proportionate to some function of the effective surface as already defined, and not to the immersed volume of the solid cast iron which floats upon a liquid less dense than itself.

In all these experiments the mass of the molten cast iron was large in proportion to the pieces placed upon it, and the surface was kept by careful skimming almost perfectly free from scoriæ or oxyde. A good deal of difficulty exists in observing the phenomena in such experiments as these, owing to the glare and heat of the molten metal. Whatever light these five experiments may throw upon the nature of the force which produces flotation, the subject must as yet be viewed as very incomplete. There are some facts of which no complete explanation can be offered without further experimental study; such as, for example, that a piece of cold cast iron which floats on liquid iron of its own

quality if forcibly thrust to the bottom and rapidly and at once released, rises again rapidly to the surface with all the *appearance* of a *buoyant* body, which it certainly cannot be.

From what precedes, however, we may summarize as follows:

If F be the force which keep the solid iron floating, B the buoyancy ± of the solid piece, and R the repellent force, then, in the case of a piece floating upon molten iron of its own quality, B is always negative, and F=R−B, the value of R for any given case depending upon the *effective surface* of the solid, and that of B upon its volume, both being modified by the initial difference in temperature between the solid and liquid metals. In the case of the solid being placed on liquid cast iron differing in quality from it, B may be either positive or negative, and R still dependent upon the conditions already stated. Hence in any such case we may have

$$F=R-B \text{ or } =R+B.$$

These conditions kept in view may clear up many phenomena at first apparently anomalous.

[However feeble may be the ascending currents, above referred to, upon the floating disks in Experiment 5, their effect must be viewed as proportionate to the lower surfaces, and therefore proportionate to the repellent force, and as possibly adding, though slightly, to its effect.]

The following experiments were made at the Royal Arsenal, Woolwich, with a view to ascertain whether any sensible expansive force could be recognized as due to the enlargement in volume by consolidation of a spherical mass of cast iron:—Two spherical bomb-shells, each of about 10″ in diameter and 1″.5 in thickness, whose external orthogonal diameters had been carefully taken when at atmospheric temperature (about 53° Fahr.), were both heated in an oven-furnace. One of these having been thus heated, but not to a *very* bright red, was permitted gradually to cool again, and its final dimension when cold noted. The other shell was withdrawn from the oven when at a bright red heat, and immediately filled to a little above the inner orifice of the fuse-hole with molten cast iron, the quality of this being the very dense mottled gray iron smelted at Elswick Works from the Riddesdale ores, and used in the arsenal for casting projectiles. The fuse-hole was closed by a screw-plug, which, however, did not reach within an inch of the surface of the molten metal, and the whole surrounded by a sheet-iron screen to keep off currents of air, was allowed to cool gradually, the dimensions being taken of the sphere as it cooled and contracted at intervals of half an hour until it had become cold. The enveloping shell was then cut through by the lathe in a great circle at right angles to the axis passing through the fuse-hole. One of the halves of the shell being detached, the interior surfaces of both hemispheres were found in perfect contact with that of the ball of iron they had contained, but no elastic tension seemed to exist in the shell. The ball of iron was drilled into and split by steel taper plugs, and sections of it exposed passing through the diameter in a line with the axis of the fuse-hole. There was no large cavity or "draw" anywhere in the interior, but there were two very small irregular cavities very near the fuse-hole; and the central portion of the mass embraced by an imaginary sphere of about 3″ in diameter, proved to be "spongy" and granular, as compared with the very dense and close-grained iron that constituted the remainder of the ball.

The following Table shows the course of contraction in dimensions of the filled shell and also of the empty shell in their progress of cooling:

[*See Table following page.*]

The object of heating and cooling the empty shell was to ascertain what amount, if any, of permanent enlargement it might suffer, it being a well-known fact that all solids of revolution of cast iron, and generally of all metals of sufficient rigidity, become permanently enlarged by being heated red-hot and permitted to cool. This arises from the fact that the outer *couches* of the solid (a sphere for example) are the first heated and expanded, and have to draw off more or less from the less-heated mass within. Tangential thrusts and radial tensions are thus produced in the material of the outer *couches* which disappear, or even become reversed, as the progress of heating reaches the in-

Time.		Diameter, filled shell.	Diameter, empty shell.
	Cold	9.850	9.843
11.30	Put in oven-furnace (shell to be filled)		
12.30	Put in oven-furnace (empty shell)		
12.15	Withdrawn from furnace	10.020	
12.55	Withdrawn from furnace		9.960
	After filling with iron, diameter was	10.030 10.040	
12.50	After filling with iron, diameter was	10.040	
1.20	After filling with iron, diameter was	10.020	9.955
1.50	After filling with iron, diameter was	10.000	9.950
2.15	After filling with iron, diameter was	9.995	9.875
2.45	After filling with iron, diameter was	9.980	9.865
3.15	After filling with iron, diameter was	9.978	9.860
3.45	After filling with iron, diameter was	9.976	9.855
4.15	After filling with iron, diameter was	9.975	9.854
4.45	After filling with iron, diameter was	9.973	9.862
5.15	After filling with iron, diameter was	9.970	9.852
5.45	After filling with iron, diameter was	9.968	9.851
6.15	After filling with iron, diameter was	9.965	9.851
6.45	After filling with iron, diameter was	9.964	9.851
7.15	After filling with iron, diameter was	9.964	9.851
7.45	After filling with iron, diameter was	9.963	9.851
8.15	After filling with iron, diameter was	9.962	9.851
	When cold	9.960	9.851

terior of the mass ; but in the subsequent cooling the entire train of forces is reversed, the exterior *couches* lose heat by dissipation first, and have to accommodate by tangential tensions their dimensions to the still hotter interior, the final result being that when the whole has cooled the dimensions are greater than before the solid was heated. A 32-lb. spherical shot, which is rather more than 6 inches in diameter, can be thus permanently increased $\frac{1}{10}$ of an inch in diameter, by a single heating. It is obvious that the increase will be much less in a spherical shell than in a solid sphere, and the less as the shell is thinner. On inspecting the Table it will be seen that the empty shell had its diameter thus permanently enlarged by 0.008 of an inch ; and had it been heated to as high a temperature as the filled shell, we may allowably conclude that this enlargement would have reached 0.01 of an inch. The filled shell has had its diameter increased by the decimal 0″.11 ; and if we deduct from this the amount of permanent enlargement due to heating only, equal to that of the empty shell, we have the decimal 0.11—0.01=0.10 which has to be otherwise accounted for. This shell was at a bright red heat visible in clear daylight when filled with the liquid iron, which occupied the spherical cavity and about 0.43 in height of that of the fuse hole. The temperature of the shell visibly rose by the heat communicated from the liquid metal, and in 30 minutes after it was filled had attained its maximum, the surface being then at a bright yellow heat in daylight when the first measurement of enlarged diameter was made. The successive measurements were taken for orthogonal diameters in the direction normal to the fuse-hole by means of finely graduated steel beam calipers capable of being read to 0.002 of an inch or even less ; the dimensions set down in the Table are the means of each pair of orthogonal diameters. The shell was thus heated at the commencement, and before consolidation of its liquid contents had taken place to any considerable extent, to within probably 200° or 300° Fahr. of the temperature of the cast iron within. The shell and its contents are therefore at the commencement very nearly in the same condition as though the whole were a sphere of molten iron without any more or less rigid envelope, if such could exist. Reverting to what has been said above as to the train of forces called into play in

a cooling sphere, let us consider what has taken place here. As the heat is dissipated from the exterior of the molten mass, being transmitted through the shell, one *couche* after another of the molten metal in contact with the inner wall of the shell consolidates, the thickness constantly advancing towards the interior, where the metal is still liquid. If each of these *couches* in consolidating expanded in volume, such expansion must conspire, with the contraction constantly going on by the abasement of temperature, to produce compression in the central and as yet unsolidified portion of the mass. If, on the contrary, each *couche* as it solidifies contracts in volume (and, as is the fact, by a larger coefficient of contraction for equal small ranges of temperature before and after solidification), then the effect must be that, after the solidified crust has attained a certain thickness and sufficient rigidity, the further progress of contraction of the central portions as *they* successively solidify must be met by their tending to draw off from the solidified shell, or in other words, by a drawing-off from each other of the particles of that central portion of the sphere which last solidifies. Now the latter is exactly what has happened: a portion of the exterior and first solidified crust, reaching about an inch and half inwards from the interior of the shell, was found to have a specific gravity of 7.150 at 57° Fahr., while a portion taken close to the centre of the sphere had a specific gravity of only 7.037; and this specific gravity would have been still lower (or, in other words, the central part of the sphere would have been still more "spongy") had it not been fed by drawing downwards a portion of the liquid iron which partially filled the fuse-hole, the portion so drawn down being estimated by the volume of the cavities left at 0.400 of a cubic inch; so that but for this the specific gravity of the central spongy sphere taken at 3″ diameter would have been reduced to 6.776.

If we reduce this central spongy mass of 3″ diameter and of the last mentioned specific gravity to a density as great as that found for the exterior crust, namely 7.150, the sphere of 3″ diameter would be reduced to one of 2″.138; and it is easy to see that in that case the external diameter of the whole sphere of metal and of the containing shell would have been less in a corresponding proportion, and that thus the final dimensions of the shell would have returned to what they were at the commencement, less the permanent enlargement, as measured by that of the empty shell. If there existed, on the other hand, any sensible expansion in volume of the metal in consolidating, not only would a central "spongy" portion be impossible and the central be the densest part of the whole sphere, but an enlargement of the entire mass and of the covering shell stretched by it must have occurred, so large as to be wholly unmistakable.

[The importance of the facts elicited from this experiment cannot be too forcibly laid before the reader. Had the sphere of molten iron, losing heat from its exterior, expanded in volume as *couche* after *couche* it solidified from the exterior, the solidification constantly advancing inwards, then the central portions of the sphere when ultimately solidified *must* be found to be the *densest* portions of the whole mass; the opposite of which was found to be the fact, the central portions of the experimental sphere being, as stated, the *least dense* portions of the whole mass. This alone seems conclusively to negative the supposition of any expansion in volume in cast iron in consolidating. On examining the Table, it will be remarked that between the hours 1.50 and 2.45 there is an irregularity in the progress of contraction which might be assumed to indicate a less rate of contraction within this epoch; and it might be further assumed that this apparent reduction arose from the conjoint action of general contraction and partial expansion operating together within some part of the mass; but this view, which the writer believes would be entirely incorrect, appears sufficiently negatived by the following considerations:

1. Between the hours 1.50 and 2.45 but one caliper measurement was made, namely at 2.15, and upon this one measurement both the existence and the amount of this anomalous part of the curve depend. An error in this single caliper measurement amounting to 0.006 of an inch was sufficient to have produced it; and as the limit of reading of

the beam calipers was to a limit of 0.002 or possibly 0.001 of an inch, a mistake in the measurement at 2.15, or a misreading of only the decimal .004 or .005 at most, is sufficient to account for the anomaly.

2. It does not necessarily indicate expansion, and from the early time of its occurrence, viz. only 1 hour 25 minutes from the commencement of cooling, it seems highly improbable that it could arise from partial expansion then commencing, while as yet a very large proportion of the entire mass must have been still liquid.

3. If it were really due to expansion, it must have shown itself later in a form that would have unmistakably declared its origin.

The supposition upon which Messrs. Nasmyth and Carpenter's theory rests may be divided into two distinct propositions.

1st. That cast iron is of greater density in the molten than in the solid state.

2nd. That cast iron in the act of consolidation expands in volume. These propositions are not identical, although the second is involved in the first. The first proposition has been already disposed of, and the last recorded experiments appear conclusively to disprove the second.

The phenomena described by Messrs. Nasmyth and Carpenter, and their explanation of the circulating currents observable in large and nearly cylindrical ladles of molten iron, *appear* at first sight so confirmatory of their views as to the greater density of cast iron in the molten than in the solid state, that it seems necessary here to present the true explanation of the facts, which, so far as they are here relevant, may be best given briefly in the words of these authors:

"When a ladle of molten iron is drawn from the furnace and allowed to stand at rest, the thin coat of scoria or molten oxyde which forms on the surface of the metal is seen, as fast as it forms at the circumference of the ladle, to be swept by active convergent currents towards the centre, where it accumulates in a patch. As the fluid metal parts with some of its heat and the ladle gets hot by absorbing it, this remarkable surface-disturbance becomes less energetic." This arises from "the expansion of that portion of the molten mass which is in contact with the comparatively cool sides of the ladle, which sides act as the chief agent in despersing the heat of the melted metal; careful observation will show that the motion in question is the result of an upward current of the metal around the circumference of the ladle]. "The upward current of the metal can be seen at the rim of the ladle, where it is deflected into the convergent horizontal direction, and where it presents an elevatory appearance. It is difficult to assign to this any cause but that of expansion and consequent reduction of specific gravity of the fluid metal in contact with the sides of the pot, as, according to the generally entertained idea, the surface-currents above referred to would be in the contrary direction to that which they invariably take, *i. e.* they would diverge from the centre instead of converging to it."

The facts, so far as they are above described, are generally correct, but the explanation given is not the true one. The currents observable for some time after a large ladle (say, holding 10 tons) is first filled with molten iron are not produced by difference of temperature in different parts of the mass, but in the following way:—Such a ladle is of wrought iron, about half an inch in thickness; and to preserve this tolerably cool, even for several hours, it is lined with a coating of earthy material daubed upon the interior in a tough and plastic state, from an inch to an inch and a half in thickness, and dried within it. The lining material consists of plastic clay, with a proportion of siliceous sand beaten up together with horsedung, chaff, plasterer's cow-hair, or other fibrous material, conferring toughness upon the mass when soft and porosity when dry. This material, after drying at a temperature averaging 500° to 700° Fahr., on being exposed to contact with the molten cast iron, exhales torrents of gas and vapor, which pass upwards through the molten mass and determine the direction of its currents; and it will be obvious, on inspecting the figure, that these currents will be most powerful round the outer circumference of the mass, where each unit of its top surface has a larger proportion of lining in

proximity to it than at the central parts of the mass, where downward currents are the necessary consequence of those produced upwards at the circumference. The organic matters mixed with the lining are carbonized, and give forth the elements of water as well as nitrogen. The clay, which is a hydrous silicate of various earthy bases, gives forth its water and some of the oxygen of the peroxyde of iron which most clays contain. More or less carbonate of lime is almost always interspersed, and this gives forth carbonic acid and water. The gases thus streamed forth act mechanically by their ascent and also chemically upon molten iron, the water being decomposed, oxydizing portions of the iron and forming scoriæ, which is again more or less reduced by contact of the hydrogen and nitrogen when the latter is present. These rapid combinations and decompositions are no doubt the main cause of those singular vermicular startings referred to by Messrs. Nasmyth and Carpenter, which are familiar to every iron-founder, but which are entirely distinct from the ascending and descending currents due to the ascent of the evolved gases. That this is the true explanation is supported by the following facts :—1. After a large ladle has stood full of molten metal for some hours, and time has been given thus for the whole of the gaseous contents of the lining to be driven off, the ascending and descending currents cease to be perceptible, and if any currents at all can be discerned they are in the opposite directions. 2. If, after this, such a ladle be emptied of its contents, the lining remaining untouched and only coated with a thin shell of adherent cast iron [and oxydes and silicates of iron], and the ladle being again filled with molten iron, no such currents as at first are produced in the molten mass, the lining having been previously exhausted of its gases and vapors. That the currents described by Messrs. Nasmyth and Carpenter are *not* due to dissipation of heat from the mass through the sides of the ladle is evident from the following considerations :

A 10-ton ladle, which is about 4½ feet by 3 feet in depth, loses heat so slowly that after standing for 6 hours the molten metal is still fluid enough to make castings. Let us suppose it filled into the ladle at a temperature of 2800° to 2900° Fahr., and that after six hours it is still 200° above the temperature of solidification of cast iron, or at 2600°. The molten mass has thus lost 300° of heat in 360 minutes, or .0138 of a degree per second. We may assume this at any instant as representing the difference in temperature between two vertical columns, one at the centre and the other at the circumference of the molten mass. The linear dilatation of cast iron for one degree of Fahrenheit being 0.0000111, as deduced from its total cubic dilatation between 60° Fahr. and the temperature of fusion at which it was poured into the cone, as given in this paper and assuming the depth of the colder of these columns, whether that be at the circumference or not, to be, as stated, 36″, that of the hotter column will be 36.0000005514, and the difference between these two measures the force which alone can produce circulating currents in the mass by difference of temperature due only to cooling. This is equally true whether it be the colder column that is dilated, as supposed by Messrs. Nasmyth and Carpenter, or the hotter one, as is the fact. And if we consider the viscidity of molten cast iron, it is perfectly obvious that the circulating currents referred to by Messrs. Nasmyth and Carpenter cannot be due to so insignificant a cause.

Want of attention, or careless interpretation of the many and somewhat complicated conditions thus seen to be involved in the cooling of a solid by dissipation of its heat from its exterior has caused many serious misapprehensions on the part of experimenters as to the supposed expansion of metals in volume when consolidating. Thus, even in the case of bismuth, it has been supposed a conclusive proof of its expansion that a mass cooling in an open crucible exudes from its interior upon its top surface cauliflower-like excrescences ; but although the author does not here deny or affirm anything as to expansion being a fact in the case of bismuth, it is nevertheless obvious that such excrescences might arise merely from the grip of the crucible itself, or even of the exterior portions of the metal already solidified

contracting upon and so squeezing out portions of the still liquid interior.

It is stated on good authority that a distinguished artillery officer, in former years at the head of the Laboratory, Woolwich Arsenal, satisfied himself of the reality of the expansion of cast iron in consolidating by the following experiment :—An elongated projectile was cast, with its axis vertical, in a very thick and massive mould of cast iron, the mould being cold or nearly so ; the molten metal was introduced through a narrow aperture applied at the base of the projectile, the neck or "gate" being knocked off the instant the mould was filled. As the cooling rapidly proceeded, portions of the still fluid metal were forced out at the place where this neck was detached ; and the conclusion was come to that the exterior being already solidified such excrescence could only arise from expansion of the contained liquid metal as it solidified in succession. What really did take place, and is the true explanation of the facts, is, that when a very thick iron mould of this sort is suddenly heated by pouring molten iron into its interior, as the heat abstracted from the latter can only pass into the material of the mould at a rate determined by its conductivity, so the interior part rapidly becomes raised to a temperature enormously higher than the exterior portions, which for a time remain almost cold. The expanded interior walls of the mould push inwards as towards the points of least resistance, and so actually diminish the capacity of the mould for a time, the inner surfaces of which press upon the consolidating crust of metal within it, and so squeeze out in part its liquid contents, just as water might be squeezed from an india-rubber bottle.

It seemed desirable to obtain some experimental results in reference to the objects of this communication with lead. It has never, so far as the author is aware, been even suggested that this metal expands in consolidating. Its coefficient of dilatation by heat is enormously greater than that of cast iron, being, according to the determination of Lavoisier and Laplace, between 32° and 212° Fahr.=0.0000474 of its volume for one degree Fahr. ; so that, taking its fusing-point at 617° (Rudberg), and assuming the coefficient constant for the entire range from 60° to 617° (which is much below the truth), its dilatation when in fusion would be=0.0264 of its volume, and the specific gravity of lead at 60°=11.36 ; that of liquid lead must be *below* 11.07. Indeed this enormous amount of dilatation is impressed upon any observer who sees the rate at which the lead in casting a common bullet sinks into the neck of the mould, and the comparatively large cavity which always exists in the ball when cut in two. From its low temperature of fusion and the suddenness with which lead passes from the solid to the liquid state without any phase of intermediate viscidity, and only a brief one of crystalline brittleness, and the facility with which its surface can be kept free from dross or oxyde, this metal presents a "crucial" example for experiment in reference to our subject.

The following experiments, by the kind permission of Messrs. Pontifex & Wood, London, were made at their works :

1st. Upon the surface of a large pot of melted lead, the temperature of which was estimated at from 750° to 880° Fahr., the half of a large pig of newly smelted lead, being a semicylindrical bar of about $5'' \times 2\frac{1}{2}''$ and about 18″ long, was gently laid down horizontally ; it immediately sank to the bottom and there remained. When about half its volume was melted away, the unfused portion was drawn up to the surface and let go, when it at once sunk to the bottom again.

2d. A ball of such lead was cast, weighing $17\frac{1}{2}$ lbs., diameter about $4\frac{1}{2}''$; this was put into an empty hand-ladle, which was gently placed upon the surface of the pot of melted lead; the ladle was depressed sufficiently to fill with lead, and being left free was carried to the bottom of the pot with sufficient impetus to produce a sensible blow of the exterior of the ladle upon the bottom of the pot.

3d. A flat circular disk of about 1.25 inch in thickness, being laid gently upon the surface, after a moment's hesitation slowly went to the bottom. Another disk of 6″ diameter, by rather less than an inch in thickness, remained a few seconds longer on the surface and then sunk to the bottom ; both disks, while

they floated, had their top surfaces but very slightly elevated above that of the liquid lead. One of the disks being gently lowered into the liquid lead vertically and edgeways, at once went to the bottom.

4th. Two disks, each 6″ diameter, the one 0.57 inch and the other 0.4 inch in thickness, being gently laid flat upon the surface of the molten lead, floated, and with an emergent portion sensibly greater than that of the disks in experiment 2 and 3, and remained floating until about 1.25 of the radius had been melted away all round, when they slowly sunk in the liquid, as was proved by the slow disappearance of the slender iron wire cast into the middle of the disk for the purpose of lowering. The thinner of these two disks floated rather longer than the thicker.

5th. A plate of sheet or laminated lead, clean from the rolling-mill, of about 0″.5 in thickness and about 10″ square, being gently placed flat on the surface of the liquid lead, floated, its top surface being nearly level with that of the liquid. After about ten seconds a piece was melted off from one of the edges, when the plate canted in the opposite direction and sunk.

6th. Plates of about 0″.18 thick floated much in the same manner as the preceding. The temperature of the solid lead employed was in all cases about 70° Fahr.

It follows from these experiments that, as in the case of cast iron, the solid does not float upon the liquid lead through buoyancy, that, on the contrary, the negative buoyancy is very marked, and that the repellent force, whatever be its nature, by which flotation is produced is dependent upon the effective surface as compared with the volume of the solid.

They present also a corroboration of the view that the repellent force upon the unit of effective surface is greater as the difference of temperature between the solid and liquid metal is so.

I proceed to some remarks upon the experiments referred to at the commencement of this paper, and quoted by Messrs. Nasmyth and Carpenter, as to the floating of pieces of solidified iron furnace-slag upon the same slag when in the liquid state. It is a fact that blast-furnace slags cooled below the point at which they become rigid do very generally float upon the same slag in its molten state. It is equally true that the basic silicates which constitute the chief part of terrestrial volcanic lavas float upon the surface of these when molten. But these admissions do not suffice in any degree to support the conclusion deduced by Messrs. Nasmyth and Carpenter, that basic silicates, whether as furnace-slags or lavas, are denser in the molten than in the solidified state, nor that these bodies in the act of solidification expand in volume or decrease in density in any manner, irrespective of the formation or enlargement of cavities or gas-bubbles within them. The experiments of the author upon the total contraction of iron furnace-slags for the entire range of temperature between that of the blast-furnace and the atmosphere, made at the Barrow Iron-Works, and fully described in the author's paper on "The Nature and Origin of Volcanic Heat and Energy," printed in Phil. Trans. for 1873, leave no doubt as to the following facts:

1st. That the density of such slags at 53° Fahr. is to their density when molten and at the temperature of the blast-furnace as 1000 : 933, or, taken at the melting-point of slag, as 1000 to 983—molten slag being thus very much less dense than the same when solidified.

2d. That no expansion in volume whatever occurs in such slags at or near the instant of solidification.

The experiments of the author above referred to were made by filling cast iron slightly conical moulds with the slag run direct from the blast-furnace, and permitted to consolidate and cool therein, by which perfectly solid slightly conical blocks were obtained. From the method employed, and the very large scale upon which these experiments were conducted, it is *impossible* that any expansion in volume at or near the point of consolidation, if even of a very minute amount, could have occurred and yet have escaped notice. It is only necessary for the author here to point out that the floating of crusts of slag or lava is *not* due to the cause assigned by Messrs. Nasmyth and Carpenter; nor is it his intention to enter at any length into what are the causes of such floating when it occurs.

The following remarks, however, may be made:—It is impossible to obtain a moderate-sized fragment of solidified slag or lava free from air bubbles, and from involved or superficial cavities, which tend to float the mass when thrown upon its own material in the melted state. Those who have attentively watched large volumes of slag issuing from the blast-furnace are aware that it comes forth carrying with it a large volume of gaseous matter minutely diffused, which is pretty readily separated, and is characterized by a white vaporous cloud floating thinly over the issuing stream; if the slag be cooled rapidly, the gaseous or vaporizable bodies present become confined and render the mass vesicular, while if cooled more slowly, and with a free surface for the escape of these, the mass solidifies more solidly, often as solidly as a block of granite.

Independently of the buoyancy that is produced by the vesicularity of rapidly cooled slags, it is highly probable that relatively cold and solid slag, whose buoyancy is negative, may yet float on molten slag, whose density is less than its own, in virtue of that same repellent force which, as we have seen, acts under like conditions in the case of metals.

With respect to acid silicates, or slags analogous to glass (which, however, are not referred to by Messrs. Nasmyth and Carpenter), the author again refers to the results given in his paper (Phil. Trans. 1873). These, and indeed the circumstances attending the production and destruction of the well-known "Rupert's drops," incontestably prove that these silicates also are *less* dense in the molten than in the solid state, and that they contract violently at or near the instant of consolidation.

The author has more than once heard the opinion expressed by those engaged about blast-furnaces, that their slags do expand in consolidating, based upon a misinterpretation of the following frequently occurring circumstance: When the large parallelopipeds of slag (5 to 6 feet square by 2 to 3 feet thick) are stripped from the iron square frame which formed their edges, and are being removed upon the iron wagons on which they are cast, and still, as often happens, in a very hot state, or even with a still liquid or viscous interior, though rigid externally, it occasionally happens that such a block bursts asunder, and with a suddenness which is sufficient sometimes to scatter dangerously some of the liquid interior; or if the fracture be not so sudden, and the interior be in a viscous condition, the latter may continue for a considerable time to slowly exude in fantastic shapes from any aperture of escape left free to it. These facts have been supposed to indicate that the interior of the mass expands in consolidating. It is scarcely necessary here, however, to enter into any detail to prove that the phenomena are due to the contraction of the already solidified exterior upon the unyielding interior of the mass; the former becoming fractured by its own grip, and its material being highly elastic, often yields with apparently explosive violence like a suddenly broken spring.

[The following remarks may be made, in addition to those preceding, in contravention of the supposed expansion of slags or lavas in consolidating. It is well known that masses of mud when dried by the sun crack, the fissures penetrating nearly perpendicular from the surface and separating into more or less symmetrical prisms. Blocks of starch after desiccation present similar phenomena, which are also frequently seen exemplified by the uppermost beds of argillaceous limestone (or calp) of Ireland when first laid bare from its detrital covering. In all these cases there can be no doubt that the phenomena are due to the shrinkage of the mass in drying. But shrinkage or contraction by cooling and consolidation ought to present us with like results; and these we see actually manifest in the splitting-up of basalt into columnar prisms whose long axis are always found perpendicular to the surface by which the heat of the mass was dissipated. Such columnar separation is not confined to basalt; instances of it are abundant in lavas of every age, the surfaces of the prisms in these being sometimes straight, sometimes curved. Although much remains yet to be investigated before all the circumstances attending the splitting up of masses of basalt or lava can be said to be fully understood, yet enough is already known and clearly explained to make it certain that it is due to *contrac-*

tion of these materials as they cool; and that this form of splitting-up is wholly incompatible with that of any fissuring that could arise from the refrigeration of a mass the volume of every part of which expanded in consolidating.]

As in what precedes the hypothesis upon which the lunar volcanic theory of which Messrs. Nasmyth and Carpenter rests is proved to be without foundation, it seems needless to enlarge upon the incongruities and contradictions which the theory itself presents when fairly applied to such knowledge as we have of the volcanic features of the moon, or still more when applied, as it must be were it true, to those of our earth [assuming the materials of our earth and satellite analogous in their physical and chemical properties — an assumption made by these authors throughout their work, though without any attempt to support it by truth].

ON HYPERBOLIC WHEELS.

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Written for VAN NOSTRAND'S MAGAZINE.

THE article on spiral wheels, published by me in the *Franklin Journal*, Philadelphia, March, 1875, brought forward a lively private correspondence from which it appears that several gentlemen of high scientific attainments took considerable interest in this matter. One of these gentlemen makes the following remarks in his letter: "It is to be regretted that in addition to your article on spiral wheels the hyperbolic wheel, bearing so much resemblance with the former, was not treated by you in a similar way. Most books* that I have examined and consulted on this subject give a number of formulæ, the derivation of which is, however, not demonstrated," &c. Now, as similar remarks had been made to me by students who were desirous to study this subject more in detail, I prepared, therefore, some time ago, several diagrams, and derived some formulæ which, in my opinion, make the subject clear, and which, in order to accommodate such taking an interest in it, I shall present in the subsequent treatise.

1. HYPERBOLAID OF REVOLUTION.

The surface of this body, that is used for hyperbolic wheels, is generated by the revolution of a right line about an axis to which it is not parallel and which it does not meet. Let $a\,b$, $a_1\,b_1$ be a right line (Fig. 1) revolving about $c_1\,d_1$ as an axis horizontally projected at m. The extremity o of the perpendicular $m\,o$ of the two lines will describe the

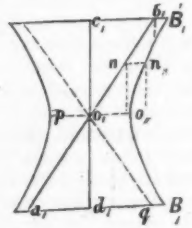
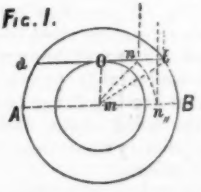


FIG. 1.



circumference of a circle called the gorge circle, and the extremities of $a\,b\,a_1\,b_1$ describe circles called the upper and lower discs. Any other point like n, n_1 generates the circumference of a circle belonging to the surface of revolution, and when turned into the meridian plane will be projected at n_{11}. In this manner any number of points of the curve $B_1 o_{11} B_1$ can be obtained; if this curve is then revolved about $c_1\,d_1$ the hyperbolic surface is produced. It is proved (Church's Dis. Geom. pp. 58 and 59) that the curve

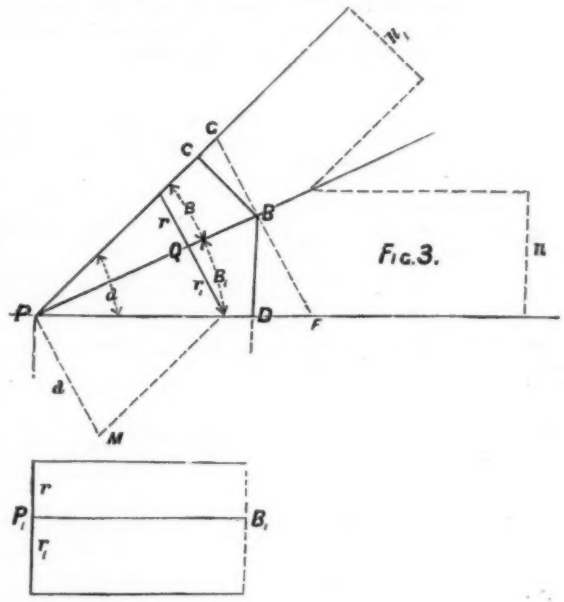
* Mr. Willis in his Principles of Mechanism gives a very thorough demonstration; but does not illustrate it by numerical examples.

$B_1 o_{11} B_1$ is a hyperbola and the lines $b_1 o_1$ and $o_1 q$ when projected on the meridian plane are the respective asymtates.

If the same line $a b$, $a_1 b_1$ revolves about another fixed line not in the same plane with it,* a second surface of revolutions will be generated tangent to the first along the generating line, and if the two solids of revolution in contact are placed in frames and motion is given to one of these it will be imparted to the other by partly rolling and sliding contact.

* The position of this second axis can, however, not be taken arbitrarily as shown in the following figures 2 and 3.

Suppose P D and P C to be two hyperboloids along the line P B, the axis P D and P C to be parallel to the vertical projection plane. We have then for the axial distance at P (Fig. 1), $a=r+r_1$, equal to the sum of the radii of the two gorge circles containing the point of contact at P. If a plane $P_1 B_1$ is passed through P_1 perpendicular to the axial line it will contain the element of contact, as this plane is parallel to both axes P C and P D (Fig. 3). Now to fix the position of P B we must know either the numbers of revolution or the numbers of teeth of both bodies. Suppose n and n_1 to be the numbers of revolution, and



N and N_1 the numbers of teeth of the bodies of revolution of which P C and P D are the respective axes. It is then $n : n_1 :: N_1 : N$, and if we assume B to be the point of contact of the upper discs, we have also :

$$B C = P B . \operatorname{Sin} \beta \text{ and } B D = P B . \operatorname{Sin} \beta_1$$

which gives

$$\frac{B C}{B D} = \frac{\operatorname{Sin} \beta}{\operatorname{Sin} \beta_1} = \frac{n_1}{n} = \frac{N}{N_1}. \qquad (1)$$

It appears then from (Fig. 3) that the angle d is divided in such a manner that the lines B D and B C, which represent the sines of β_1 and β respectively are in an inverse ratio to the numbers of revolution and in a direct ratio to the numbers of teeth.

If we put for $\beta = d - \beta_1$, we obtain :

$$\frac{\operatorname{Sin} (d - \beta_1)}{\operatorname{Sin} \beta_1} = \frac{n_1}{n} ;$$

Developing the first number we have,

$$\frac{\text{Sin } d.\ \text{Cos } \beta_1 - \text{Sin } \beta_1.\ \text{Cos } d}{\text{Sin } \beta_1} = \frac{n_1}{n}.$$ Hence

$$\text{Cotg } \beta_1 = \frac{\frac{n_1}{n} + \text{Cos } d}{\text{Sin } d}.$$ That is:

$$\text{Tang } \beta_1 = \frac{\text{Sin } d}{\frac{n_1}{n} + \text{Cos } d} \qquad (2)$$

Since the axial distance $a = r + r_1$ is perpendicular to the line of tangency, we obtain graphically the lengths of r and r_1 when we erect P M $= a$ perpendicular to P B (Fig. 3), and move P M parallel to itself till it lies between P C and P D. It appears then that r = P Q tangent B_1 and r_1 = P Q tangent B_1, which gives:

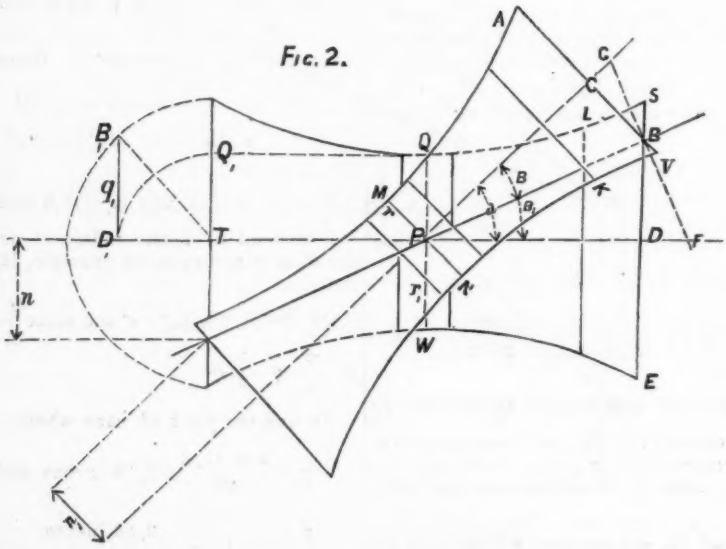
$$\frac{r}{r_1} = \frac{\text{Tang } \beta}{\text{Tang } \beta_1} = \frac{\frac{\text{Sin } d}{\frac{n}{n_1} + \text{Cos } d}}{\frac{\text{Sin } d}{\frac{n_1}{n} + \text{Cos } d}} = \frac{\frac{n_1}{n} + \text{Cos } d}{\frac{n}{n_1} + \text{Cos } d} \qquad (3)$$

but $r_1 = a - r$ introduced into (3) we find:

$$\frac{r}{a} = \frac{1 + \frac{n}{n_1}.\ \text{Cos } d}{1 + 2\frac{n}{n_1}.\ \text{Cos } d + \left(\frac{n}{n_1}\right)^2} \qquad (4)$$

These equations then determine the respective radii of the gorge circles and point of tangency when the axial distance $= a$, and the respective numbers of teeth or numbers of revolution N, N and n_1 n are known.

FIG. 2.



Finally, it is required on the other hand to find the two radii of the upper discs as C V and D S (Fig. 2), which may be obtained in the subsequent manner. Since the plane $P_1 B_1$ contains the line of contact—P B passing through the line of tangency which latter contains the points of contact P and B. Therefore D B $=$ $D_1 B_1$ and T Q $=$ P Q $= r$, (Fig. 2). Hence if the line P B $= l$ is assumed, we find:

Since D B = P B. $\text{Sin } \beta_1 = l. \times \text{Sin } \beta_1 = q_1 = D_1 B_1$ (5)

$R_1 = D S = T B_1 = \sqrt{r_1^2 + q_1^2}$ and

$R = C V \sqrt{r^2 + q^2}$; where $q = l.\ \text{Sin } \beta.$

Introducing into the above derived general formulæ, particular angles we obtain, for example, $d=90°$ from (4).

$$\frac{r}{r_1}=\text{tang}^2\ \beta=\left(\frac{n_1}{n}\right)^2 \quad (6)$$ and

$$\left.\begin{aligned}\frac{r}{a}&=\frac{n_1^2}{n^2+n_1^2}\\ \text{and on the other hand}\\ \frac{r_1}{a}&=\frac{n^2}{n_1^2+n}\end{aligned}\right\} \quad (7)$$

For $d=0$ the hyperbolic wheels pass into common spur wheels.

The subsequent numerical example will explain the use of the preceding formulæ, and how they are applied in constructing these wheels.

1. *Example.*—Given the axial distance $a=10$ inches and $\frac{n_1}{n}=\frac{1}{2}$; further the axial angle of projection $d=60°$. It is required to find the radii of the gorge circles and upper discs, also the position of the line of contact.

To find r and r_1 we have from formulæ (4)

$$\frac{r}{10}=\frac{1+2.\text{Cos}\,60}{1+2.\,2\,\text{Cos}\,60+4}=\frac{1+1}{3+4}=\frac{2}{7};\ \text{hence}$$

$r=\frac{20}{7}$=inches, and $r_1=10-\frac{20}{7}=\frac{50}{7}$inches

To find β and β_1 we have from (2)

$$\text{Tang}\ \beta_1=\frac{\text{Sin}\,60}{\frac{1}{2}+\text{Cos}\,60}=\frac{0{,}866}{\frac{1}{2}+\frac{1}{2}}=0{,}866.$$

Hence

$\beta_1=40.°\ 53'$ and $\beta=60-40°\ 53=19.°\ 7'$.

Assuming the distance from the points of tangency of the gorge circles and the upper discs $l=18$ inches, we find from (5).

$$R_1=\sqrt{(18.\ \text{Sin}\,40.53)^2+\left(\frac{50}{7}\right)^2}=13{,}8\ \text{in.}$$

$$R=\sqrt{(18.\ \text{Sin}\,19.7)^2+\left(\frac{20}{7}\right)^2}=6{,}52\ \text{in.}$$

2. *Example.*—Given N=15 and N_1=27 (number of teeth), further the axial distance $a=5$ inches, and the axial angle $d=90°$, also the length of line of contact $l=12$ inches. It is required to find the radii of the gorge circles and those of the upper discs and the pitch. To perform the division of the angle $d=90$ into β and β_1, we have from (6):

$$\text{Tang}^2\beta=\left(\frac{n_1}{n}\right)^2=\left(\frac{N}{N_1}\right)^2=\left(\frac{15}{27}\right)^2\ \text{whence}$$

Tang $\beta=\frac{5}{9}=0{,}555\ldots$ Hence

$B=29.°\ 3'$ while $\beta_1=d-\beta=60°-29.°\ 3'$
$=40°\ 57'$.

To obtain r and r_1 we have from (7), and since $n_1=\frac{5}{9}\,n$.

$$\frac{r}{5}=\frac{(\frac{5}{9}\,n)^2}{n^2+(\frac{5}{9}\,n)^2}=\frac{(\frac{5}{9})^2}{1+(\frac{5}{9})^2}=\frac{25}{106}$$

Hence $r=\frac{125}{106}=1{,}18$, while $r_1=5-1{,}18=$
3,82 inches.

To find the two radii of the upper discs in contact, we have the perpendicular distances from the point of contact to the respective axis:

$q=l.\ \text{Sin}\,\beta=12.\ \text{Sin}\ 29°\ 3'$. Hence

$$R=\sqrt{(12.\ \text{Sin}\ 29\ 3)^2+(1{,}18)^2}$$

and $R_1=\sqrt{(12.\ \text{Sin}40°57')^2+(3{,}82)^2}$

which gives

R=6,08 inches, and R_1=11,8 inches.

If instead of l_1 the radius of one of the discs is assumed, for example, R_1, we find:

$q_1=l.\ \text{Sin}\,\beta_1=\sqrt{R_1^2-r^2}$ and since $\frac{q}{q_1}=\frac{n_1}{n}$

$q=\frac{n_1}{n}.\ q=\frac{5}{9}.\ q$

To find the pitch of each wheel:

$$p_1=\frac{2\ \pi.\ 11,8}{27}=2,74\ \text{inches, and}$$

$$p=\frac{2\ \pi.\ 6,08}{15}=2,54\ \text{inches.}$$

While two spiral wheels in contact have only one point common, it appears that two hyperbolic wheels touch along the whole element, and while the sum of the tangential angles and axial angle of two spiral wheels in contact amounts to 180°; the axial angle of the hyperbolic wheel limits the tangential angle, which indicates that a less number of varieties of hyperbolic wheels is

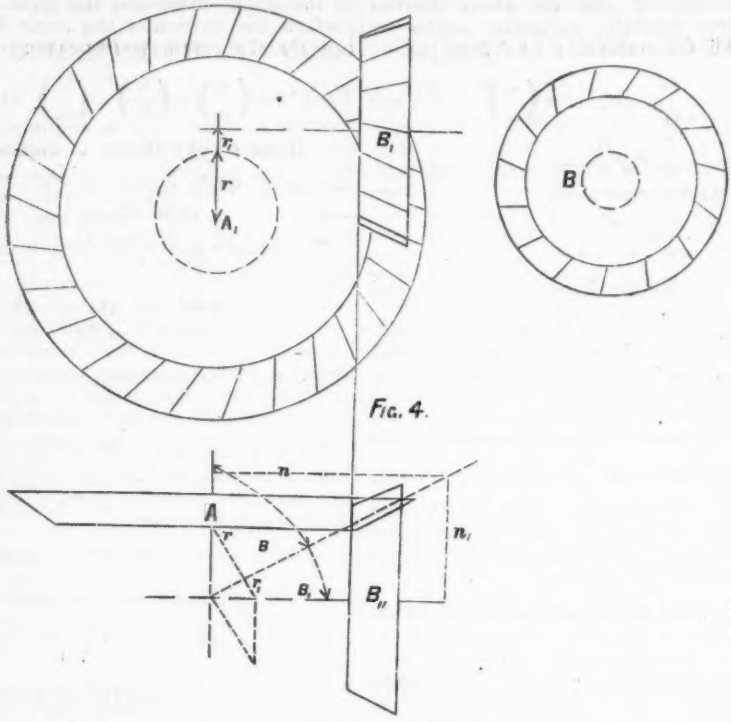


Fig. 4.

possible than of spiral wheels, a fact that has often been overlooked in applying these two kinds of wheels.

In practice, as in the case of conic wheels, a narrow frustrum only is required of each hyperboloid (Fig. 4), and these parts include so small a portion of the curve that straight lines may be substituted without sensible error. Several wooden models, which were made in accordance with the above calculation, work very well; some of them work by friction only produced by the pressure upon the surface of contact, others were furnished with teeth of a similar form to those of conic wheels.

As to the axial positions, the hyperbolic wheels bear much analogy with spiral wheels. The above (Fig. 4) represents the above mentioned thin frusta where the positions of the teeth are indicated by right lines obtained from the common line of contact.

SPANISH MINING.—In the mining district of Mansilla, Logrono, Old Castile, two Ferroux rock-drills, to be worked by steam power, are being put up by the Swiss firm of B. Roy & Co., of Vevey. The scarcity of labor is much felt in the mining districts of Spain. The *Revista Minera* states that these two rock-drills are the first drills that have been yet used in the country. Great animation is reported from the mining district of Teruel. By a decree of the Governor of Biscay the exportation from Bilbao is prohibited of gunpowder, sulphur, saltpetre, dynamite, petroleum, lead, raw or worked, brass, tin, tin-plate, copper and iron, whether ore or metal, and every class of coal. By royal ordinance of June 12th, steel rails pay the same import dues with iron ores. The directors of the mining undertaking of the basin of Belmez and Espiel are endeavoring to obtain a railway direct between Madrid and Ciudad-Real.

THE CHANNEL TUNNEL—POSITION OF THE ENTERPRISE.

From "The Builder."

At length this vast enterprise, which, if completed, will certainly confer upon the engineering genius of the nineteenth century a conspicuous fame, has a chance of triumph over all the obstacles that have been predicted. The latest measures in connection with the project have been of the utmost importance. A bill has passed the two Houses of Parliament, authorizing the acquisition of certain lands in the parish of St. Margaret at Cliffe, in the county of Kent; and, at the same time, the French Assembly, before its dispersion, gave at least nominal effect to a scheme for opening similar works on the opposite shore of the British Channel at Sangatte. Neither in the English nor in the French Reports or Bills is there found a full explanation of the plans, as they lie now, in manuscript, at the Board of Trade; but an examination of the documents, or the raw official materials of which they are composed, suffices to inform us as to the actual state of the question. It is simply this:—In the year 1862 a company was incorporated to construct an underground, and also submarine, tunnel between England and France, with all necessary approaches, accessories, and conveniences, so as to afford the means of perfect land communication between the two countries, and the powers it proposed to claim were legally justified. It would be superfluous to enter upon the legislative wranglings over plans, acts to be abolished or construed, purchases, and costs, since the principal importance of the subject to the public consists in the mighty mechanical work to be undertaken. This will not be, at the outset, it may be as well to explain, an attempt directly to tunnel beneath the Channel for a railway line. It is only contemplated, according to the last statements deposited at the Board of Trade, to examine into the probabilities, or possibilities, of opening a way for the locomotive and the train at a safe depth below the sea. The present idea, then, is to sink, on both sides of the Channel, at particular points which are indicated, shafts through the gray chalk, or that which is almost nonporous and impermeable by water, and thence to conduct an excavation tending to meet from opposite ends, which should equal,—as it would, if triumphant, more than equal,—the perforation of Mont Cenis. However, the lawyer's aspects of the question are, at this stage, of little importance; the two Governments are agreed, and the thing has now only to be done. But what millions have been sunk in an effort to cross the British Channel, and conquer that "thin streak of sea-sickness" which, as popular tradition still asserts, frightened the famous Boulogne flotilla! Leaving out of consideration four of the Channel ports,—Hamburg, Rotterdam, Antwerp, and Ostend, as well as Havre and Dieppe, upon which this achievement, by the way, would not inflict any great injury, because they are commercial, rather than passenger, ports,—it is the narrowest sea which is the most formidable, which is, indeed, the "moat" of the Continent. The sufferers who, in default of a subway or drawbridge, endured the tortures of this brief passage, amounted last year to nearly half a million, and no number of *Castalias* or *Bessemers*, no matter how scientifically built, can meet the demand for those who feel an ineradicable hatred of salt and swelling water. There are excellent steamers, no doubt, employed upon the Channel service already, but where and what are the harbors? It is not the mere Channel passenger who finds himself inconvenienced. The invalid from Australia, or India, often declares that this bit of chopping sea-current is the most trying part of his voyage. He hates it worse than the rollers of the Atlantic, or the sultry nights of the Red Sea. Thus affirms, at any rate, Captain Tyler, whose report is in course of preparation for the next session of Parliament. His estimates concerning this little water journey between France and England are of peculiar interest. There is an average, he says, in the course of the year, of thirty storms; of 100 days bringing with them heavy seas and troublesome breezes; of 108 moder-

ate days happening in succession; and 90 of cold weather. The two opposite coasts, so to speak, are hostile in character,—what with their cliffs, bars, sands, necessity for breakwaters, masonry, piers, curves, capes, and shallows; and the problem has been, for many years, how to avoid the dilemma so long felt. Calais is, undoubtedly, so to speak, the English harbor of France. It may be, geographically, a little less direct on the road to Paris than Boulogne; but it has been selected, whether for one reason or another, as the great centre of communication, by way of Brussels and Cologne, for Strasburg, the Rhine, the North of Europe, and North and South Germany. There is nothing, therefore, to be wondered at in the circumstance that so constant desire should have existed, or so continuous an endeavor been made, to abridge and facilitate this traffic, which, it may be said without exaggeration, is vital to the common life of Europe.

In the first place, however, it was deemed necessary to ascertain the probability of successful excavation. Geologically, the bed, and, nautically, the depths, of the Channel, are well known; yet sufficient has been ascertained, in other respects, to induce an opinion that the experiments should be undertaken, not precisely at Calais, but at a point near Ambleteuse, near the familiar village of Andresselles, where the deepest water, near that coast, is to be found. Originally, as every one is aware, the project was regarded as an impossibility, and enormous steamers, or ferry-boats, were suggested, which would have involved a world of new piers, basins and sluice-gates; indeed, the fluctuations of ideas upon the subject has been the chief cause of its being left so long to wither in the pigeon-holes of speculation. After the great ferry scheme had broken down, the designs of Mathieu, the French engineer, for a Channel tunnel were deliberately brought upon the carpet, but as deliberately brushed away; for they were lost, and have never been recovered. Gamond came next, with a series of geological demonstrations, which have sustained the criticisms of time and science, and, at his instance, a Commission was granted by the late Emperor of the French, "which," in the language of the report, "appears to have come to the conclusion that it was desirable to test his investigations by sinking shafts and driving short headings under the sea, at the joint expense of the two Governments." But this is a French rather than an English view of the matter. Another countryman of our own, Mr. Low, also laid a plan before the Emperor, in 1867, as Sir John Hawkshaw had done, with even more elaboration, in the previous year, and Mr. Remington in 1865,—and their rivals, whose names deserve to be noted, although their ideas cannot be here described at length, were, —MM. Franchot, Tessier, Favre, Mayer, Dunn, Austin, Sankey, Boutet, Hawkins Simpson, Boydon and Brunlees. It is worth while to observe the list, because, if the work has not yet been accomplished, it has evidently not been for want of ingenuity and will. It has miscarried, however, to a certain extent, through the variety and contradiction of the schemes projected. Apparently, this difficulty has been overcome, and the resolve has been arrived at definitely to pierce the stiff gray chalk. Mr. Remington, as appears from the printed remarks forwarded by him to the Board of Trade, would have selected the line from Dungeness to Cape Grisnez, in order to avoid the chalk and fissures which he dreads encountering in the bed of the Channel, and to work in the Wealden formation, which he believes would afford a greater chance of success. Such is the latest aspect of the matter, as presented to the Department at Whitehall. But the report does not stop short here. It recapitulates the dreams, as some of them may indeed be termed, of other adventurous engineers. There were two or three who proposed bridging the Channel, and one actually professed himself prepared to build a "marine viaduct" from Dover to Cape Grisnez, with iron girders propped on 190 towers, 500 ft. apart, and 500 ft. above the water, and he estimates the cost of such an edifice at simply £30,000,000! Again, there was, as already mentioned, Mr. Hawkins Simpson, with his submarine tunnel on a pneumatic system, called by him, however, the "Eolian" principle, for which he claims the merits of cheapness, expedition, superior ventilation, and easier utility. It is interesting to

note the inexhaustibility of inventors in these respects. There is Mr. Alexander Vacherot, who has submitted to the Board of Trade a scheme which, we ought to say, he laid before the Emperor of the French in 1856, for "laying on the bed of the sea a tunnel made, or formed, so as to constitute, so to speak, a monolith." He would "construct it on the shore," and "complete it in sections, to be drawn down into their places when finished."

The representative officer of the department dismisses most of these projects with a critical, yet downright, denial of their practicability, and his language may be worth quoting :—"Although it was desirable to advert to these various expedients, it is not necessary, in this place, to say more in regard to them, than that, while I am unable to convince myself of the feasibility of any bridge scheme, I conceive that it might be wise to test the practicability of a tunnel by means of preliminary driftways." This is precisely what it has been agreed, by both Governments, both Legislatures, and the united companies, shall be done. It is true that not far from forty years have elapsed since M. Thomé de Gamond first attempted to prove that a submarine thoroughfare, between the two countries, was possible; but gigantic advances have been made, during the interval, no less in opinion than in science and mechanics. No international fears are now created by the Mont Cenis excavation, or the Suez Canal. They are regarded, indeed, as treaties and pledges among the Powers of civilization. The shores of the Atlantic have been united by a cable; the barrier of the Alps has been virtually destroyed; and, with reference to the latest and, perhaps, grandest project, a careful geological survey has shown, at any rate, the possibility of cutting a tunnel through the narrowest, or almost the narrowest, part of what are sometimes designated as the Straits of Dover, a distance of twenty-two miles, or slightly more. Trial borings and soundings taken at different points by Sir John Hawkshaw and the late Mr. Brassey indicate a bed of chalk as the stratum through which, after leaving the coasts on either side, the perforation is to be made. Of course, on the freedom of this bed from accidental fissures, dislocations, and "faults," the success or failure of the vast experiment depends; but there is every reason for believing that it lies in a mass, continuous and compact, between, as it were, two impenetrable ramparts of clay. From the boring on the English coast, in St. Margaret's Bay, a great unbroken depth exists,—175 ft. of "upper" chalk, and 295 ft. of "lower" or gray, chalk which is occasionally confounded with the clay itself; while the workings on the French side, near Sangatte, show 270 ft. of the upper, and 480 ft. of the lower. Experimental shafts, on a narrow scale, resembling somewhat the borings for an artesian well have been carried to a depth of 600 ft.; but these supplemental demonstrations, in point of fact, were superfluous, the main object being to ascertain the depth and nature of the Channel bottom, which, at its deepest, is 180 ft., and its average rather more than 100 ft. below the surface of the water. No sudden changes of profundity, and no reefs or banks, are discernible, to the knowledge of the most experienced men, and the bed of the "thin streak" is shown to be a gradual and almost equally rising and falling concavity between the two coasts. Under these conditions, as the reports inform us, and taking into account the deep homogeneous strata to be bored—about 500 ft. thick—not less anywhere than 200 ft. between the crown of the arch and the bed of the Channel (allowing for the precipitous cliffs on either side)—every hope may be entertained that the enterprise, though so incomparably superior in its magnitude to that of Isambard Brunel for constructing a Thames subway, will be successful. The Thames Tunnel was, indeed, in some respects, a more hazardous enterprise. Little was then known about sub-aqueous boring; the materials were more shifting than those which the Channel excavators will have to encounter,—irregular strata of loose earth, masses of sand, gravel, mud, and clay, liable to constant disturbance; and a formidable tidal action. In remembrance of these obstacles, it was thought that a tunnel beneath the sea must present insuperable difficulties. But we have gone through the great submarine galleries of the Cornish, Cumberland, and other mines, and observed

no more drip than would be evident in any cavern of the Derbyshire Peak. For instance, the mine of Shiel Lode runs to a length of 80 fathoms below the level of the sea, at a depth of less than 18 ft. from the water. It has never been inundated, nor have the workmen (workwomen also, we are sorry to add) suffered through deficiency of ventilation, space, and provisions for their comfort. To conclude, practically, however, the first boring is to be about 9 ft. each way, which dimensions are asserted are the least that can be depended upon as a test, or even as an experiment. Then will follow the work of enlargement, along the walls and roof, through the agency of a machine which, it is affirmed, can bore chalk at the rate of a yard, or more, an hour. A difficulty, however, may still have to be met. The most costly labor of any will be the removal of the excavated stone, clay, and soil. Tunnels driven underground have usually shafts, at intervals, through which the disturbed earth is raised, and their frequency, by enabling the excavation to be broken up into short lengths, reduces considerably the arduousness of the work. Such advantages, however, will not exist in the case of the projected Channel Tunnel. All the earth, or rock, or clay, or chalk will have to be removed to the terminal shafts at either end, and this toil and expenditure must increase as, by progression of industry, the headings are removed to greater distances from the ends. Nevertheless, the task is now fairly in hand, and we may rely upon the spirit and the genius of the age in which we live to carry it through effectually.

RELATIONS OF TITANIUM TO IRON.

By RICHARD AKERMAN, of the Stockholm School of Mines.

From "Iron."

Titanium occurs in many iron ores, and sometimes in very large quantity. Thus a magnetic iron ore from Ulfö, in the Archipelago of Angermanland, contains, according to an analysis by Dr. A. Tamm, 9.51 per cent. titanic acid. Further, Herr Fernquist has found in a magnetic iron ore from Taberg, near Jönköping, 6.30 per cent.; and in a magnetic iron ore from Longhult Mine, in Smoland, 8.5 per cent. titanic acid. Finally, in similar ore from Inglamola, in the same province, 5 per cent. titanic acid has been found.

Titanium is very difficult to reduce, and the incomparably greatest part of an iron ore's content of this substance passes in the furnace process into the slag, the color of which, in consequence, becomes dark to completely black, while in the pig-iron produced it is commonly difficult to detect the least trace of it. Thus Herr J. E. Eklund, in an examination made at the Stockholm School of Mines, found scarcely a trace of titanium in the pig-iron produced from the ore from Taberg, mentioned above; but the slag belonging to it, on the contrary, contained 8.55 per cent. titanic acid, and another furnace-slag from Taberg ore has been found to contain 10 per cent. titanic acid.

Professor Eggertz, too, while assaying very titaniferous iron ores, has never succeeded in obtaining any titanium in the pig-iron produced. Nor did any success attend an experiment made in Percy's laboratory to produce titaniferous iron by fusing together oxyde of iron and finely pulverized titanic acid in a graphite crucible, inasmuch as no titanium was found in the metallic buttons produced; but Sefström on the contrary —probably in consequence of stronger blowing, and the higher temperature thereby occasioned—obtained a very titaniferous iron by heating, in a graphite crucible, a mixture of oxyde of iron and titanic acid, and a similar mixture along with the bisilicate of lime. In the former case he obtained a very hard but malleable iron, with 4.78 per cent. titanium; and in the latter a velvet black soft iron, with 2.2 per cent. titanium.

In a third experiment, similar to the second, there was obtained an unmalleable white and hard pig-iron, with 0.5 per cent. titanium. That this substance is sometimes also found in pig-iron produced in the common way appears from the fact that Mr. Riley, after several unsuccessful trials with different varieties of pig-iron, finally found, in several which were produced partly from titaniferous bog ore from Ireland, very considerable contents of titanium, or from 0.5 to 1.6 per cent. Further, Rammelsberg has found a small content of titanium in a spiegeleisen from Lohhütte, in Müsen, and finally Karsten says that a trace of titanium may be found in many varieties of pig-iron.

Besides occurring in the furnace-slag, titanium is also found in copper-colored compounds which are found most frequently in the form of small cubical crystals, but also in an uncrystallized state, partly on the bottom and walls of the furnace, partly in the so-called pig-iron clots, and partly also in the slag itself. These were at first believed to consist of metallic titanium, but, according to Wöhler, their composition is represented by the formula $TiC^2N^2, + 3Ti^2N^2$. This compound of titanium may, according to Herr Zincken, be volatilized at a high temperature, and its occurrence is by Wöhler considered to be connected with the formation of the cyanide of potassium in the furnace.

In the dry assay of titaniferous iron ores there is commonly observed between the pig-iron and the slag, and also around both, a copper red film, which, in all probability, also consists of the compound of titanium just mentioned. Karsten further states that he also found in pig-iron small red grains, and that it is only in the pig-iron in which they occur, that any noticeable content of titanium is found, in consequence of which he doubts whether iron and titanium can enter into any true chemical combination with each other.

Ores, rich in titanium are, as has already been mentioned, specially difficult of reduction, so that the quantity of fuel required for their dry assay is much greater than when other ores are employed, and this circumstance may perhaps be explained in this way, that the titanic oxyde or acid indirectly increases the difficulty of reduction, inasmuch as it tends to retain a part of the oxyde of iron in combination with itself. When the black slag obtained in the dry assay from titaniferous iron ores, has been fused several times in succession, in a graphite crucible, small buttons of pig-iron have, according to J. Akerman, been obtained every time; but the remaining slag has been still of the same degree of blackness. It is also remarkable that titaniferous iron ores are often smelted in a graphite crucible with the same result, whether they are fluxed with lime or quartz.

The salts of titanium are fusible with difficulty, on which account titanium makes a charge difficult to smelt; but, notwithstanding all this, it may yet be a question if titanium is not favorable to the formation of spiegeleisen. It cannot be considered as absolutely established, but it is a fact, that spiegeleisen can very readily be produced from Taberg ore, notwithstanding the small quantity of manganese (0.4 per cent. protoxyde of manganese); and this ore, notwithstanding its richness in magnesia (18.3 per cent.) and poverty in iron (31.5 per cent.), differs from the Swedish ores only in this that it contains a litttle vanadium and a great deal of titanium. Somewhat larger percentages of manganese have indeed sometimes been found in Taberg ore than that mentioned above; but that the fitness of this ore for the production of spiegeleisen must be derived from some other cause than the common one—that is to say, the presence of manganese—is believed to be shown by the fact that two pieces of spiegeleisen from different works in Taberg district, analyzed at the Stockholm School of Mines, contained 0.15 to 0.2 per cent. manganese; and it appears probable, therefore, that either vanadium or titanium is the cause wherefore spiegeleisen is so easily formed from this ore.

Ulfö ore has, in consequence of the difficulty of reducing it, been used only to inconsiderable extent, and, as far as I know, no spiegeleisen has been produced from it; but that it tends to give a white pig-iron appears from Clason's experience that when not more than 19.4 per cent. of a basic charge, which previously gave dark gray pig-iron, was at

Bollsta furnace exchanged for Ulfö ore, the iron became white, with only here and there a gray speck interspersed. Titanium may possibly therefore favor the tendency in iron to combine with the carbon occurring in it; but if this is in truth the cause of the phenomena just mentioned, the action of titanium must be very powerful, for the pig-irons thus produced have been found to contain, as has been already mentioned, scarcely a trace of the substance in question. However this may be, it is worthy of notice that the specimen of spiegeleisen from Taberg has not been found to contain more carbon than common charcoal-pig, and that it is not brittle like other spiegeleisen, but, on the contrary, very difficult to break in pieces.

With reference to the difficulty of reducing titanium, and its tendency to combine with oxygen, it is probable that the titanium sometimes occurring in pig-iron is oxydized during the refining process, and in malleable iron, so far as I know, titanium has never been found.

By fusing together 99 parts of steel and one part of metallic titanium Karsten obtained a good steel throughout, but its content of titanium was very variable, and Karsten finds in this circumstance an additional support to his views that titanium and iron in the metallic state do not enter into any true chemical combination, but are merely mechanically mixed with each other. This steel, after polishing and etching, took on a very fine damascening.

Faraday and Stodart have attempted, by fusing together steel filings and a mixture of charcoal in one case with titanic acid, and in another with titaniferous iron sand, to produce titanic steel. In this way, too, a good steel was obtained which took on damascening, but no trace of titanium could be discovered in it, and this notwithstanding that a specially high temperature was employed for its production.

From what has been stated it is thought to follow that it is only exceptionally that any reduction of titanium has taken place in the case of mixtures of titanic acid or compounds of oxydes of titanium with iron and charcoal. Attempts have been made to produce titanic steel by fusing together compounds of titanic acid with charcoal and iron, but Percy states that many well-known analysts have sought for titanium in such steel without success; and, without setting up for a judge in this question, I may add that I have not found any titanium in such steel. This is also the case with Mr. Riley, who has taken so much trouble with determinations of titanium, and who found so considerable quantities in some varieties of pig-iron.

To how great an extent the titanium crotchet has been carried is best seen from the circumstance that the superiority of Dannemora iron, and other first-rate brands of steel-iron, has been attributed to the richness in titanium of the ores used in their production the fact being that, so far as I know, no titanium has been found either in Dannemora ores or in any of the other Swedish ores, from which the most renowned varieties of steel-iron are produced.

From the facts above stated it appears to follow that if titanium is of any observable use in the manufacture of steel, its influence on the qualities of the iron must be so exceedingly strong that so small a quantity as can with difficulty be discovered by analysis acts upon it; and this is confirmed, to some extent, by the fitness of Taberg ore for the production of spiegeleisen; or the influence of titanium must be indirect, by conducing to the removal of substances hurtful to the steel. This perhaps may be the case, at least so far as sulphur is concerned, for at the furnaces where Ulfo ore is used it is believed that the danger of red-shortness is considerably diminished by a mixture of less than 10 per cent. Ulfo ore in a charge containing sulphur. There are those also who affirm that titanium purifies from phosphorus, but I know of no facts to prove this. On the other hand, it is contradicted by the fact that Dr. A. Tamm has, in the pig-iron produced in the dry assay of Ulfo ore at the School of Mines, recovered the whole of its content of phosphorus, which, however, was so small (the ore containing only 0.07 phosphoric acid) that a final conclusion can scarcely be deduced from this experiment.

THE dismissal of European employés on the East Indian Railway has been stopped by the Supreme Government.

THE MAIN DRAINAGE OF PARIS.

From "The Building News."

Almost coincidently with the formal completion of the main drainage system in London has been issued a statement from those who may, in English phrase, be termed the Commissioners of the Seine, on a precisely kindred subject in Paris. It begins by contradicting the popular, and especially the foreign, idea that the capital of France is a dry city —asserting, on the contrary, that the average daily rainfall equals half the amount artificially supplied for the consumption of all the inhabitants. Tide floods, which, mingle together, contaminated by the pollutions of streets, of dirty roofs, and all else constituting an infectious flow wherever any population, great or small, is gathered together, must be got rid of systematically, somehow. The gutters, sinks, vertical pipes down the fronts of houses, the gratings and runnels in the streets, were useless without the immense number of subterranean canals carrying off all this excess, at a point far from Paris, into the river, though necessarily not so near to the sea, as are our own sewage outfalls. There is a curious, though not an exact, parallelism between the history of the two systems. That of the English metropolis was ordered by Act of Parliament to be carried out in the year 1858; in the same year that of the French metropolis was completed. It is needless to dwell upon the crying necessities which existed for both; but Paris was, perhaps, in the worse condition of the two. In distant times the state of her streets was an abomination patent to the eyes even of those who looked out from palace windows: in more modern days the evil became so intolerable that wealthy private individuals protected their lives by draining, at their own expense, the thoroughfares in which they resided. Later still, after a storm, the streets of the lower town had to be crossed on temporary wheeled bridges, always kept in readiness; and, so late as 1839, a petition of the inhabitants represented to the Government that whole quarters would be depopulated if some abatement of the evil did not take place. Even then nearly twenty years elapsed before the grand reform was effected; but it was a real one, and upon a magnificent scale. The French, who are fond of splendid phraseology, declared that a new or underground Paris had been created; but, apart from the national habit of verbal exaggeration, it was perfectly true that an immense work had been accomplished in the face of stupendous difficulties. For, at that time, and since, the city was being converted above, as well as below, by means of new streets, squares, public edifices, and railway termini; and it was, moreover, found that there were three miles of habitations for every mile of sewer. The task at that time taken in hand occupied about nine years in its fulfillment, and the results have been now about eighteen years in operation. That their success has been great, as the Administration asserts, is not to be denied. It has had the happiest effects upon the health, the pleasantness, and even the external aspects of Paris; but that nothing remains to be done, more particularly in the outer circle of the city, not even the Board, as we should term it, of "Bridges and Roads" attempts to show. Indeed, its primary object in drawing the attention of the Minister to the subject is that he may be induced to support a supplemental plan for bringing within the cope of the Parisian main drainage system the outlying yet contiguous districts, which can scarcely any longer be regarded as suburbs. The undertaking, it is urged, would be neither formidable in the obstacles presented by it, nor costly in the execution, because—the argument is an official one, be it remembered, and not altogether supported by experience—the existing chief arteries, constructed, not to answer the purposes of a generation or two, but designed upon a scale of more than Roman grandeur—literally—are capable of receiving any number of affluents that could possibly be directed into them. In magnitude, of course, they do not approach those of London, but, in every other respect, they are not less remarkable. The entire arrangements is dis-

tinguished under two heads—principal arteries and feeders. Little value is assigned to pumping stations or reservoirs. The French comparison, in fact, is that of a fish's skeleton running beneath the roadway: the dorsal bone is the "collector," the lateral bones are the drains, whether from the houses or the gutters. The former, or the largest of them, follows the lines of the valleys which so characteristically mark the configuration of the French capital, so that they may receive the tribute of the more elevated quarters, and they are three in number: —One, on the right bank of the river, known as the "departmental," on account of its vast extent, the wide basin it drains, and its being regarded as taking precedence of the other two; and this divides into three large branches, gorged by the sewage of the worst quarters—the cattle markets, the public slaughter-houses; the gasworks, the immense industrial establishments of La Villette, Montmartre, Belleville, St. Denis, and even the crowded hamlet of Bondy. Eighteen months ago it was considered more than sufficient for any conceivable accumulation; but it is now affirmed that the outlet into the river not far from Saint Ouen is occasionally so choked that its arch threatens to burst. This, however, it is explained, may be accounted for by the fact that, at a particular point, one *embouchure* carries off the load brought down by two of the vast vaulted subways that intersect subterranean Paris. The second great collector, on the same side of the stream, starts from the Arsenal Basin, and continues its course through, a purer neighborhood, until it reaches the village of Asnières, where it vomits —to employ the word in its Roman sense—its contents into the Seine, to the infinite detriment of waters that would otherwise be delightful. The Government is urged to take this fact into consideration, in conjunction with the municipality, and to relieve, if possible, so favorite a pleasure resort of the Parisians from so noxious a neighbor. For, it is pointed out, besides the crowded tract of town between the Arsenal and the railway, it bears a pestiferous load from the Sebastopol district, the Rue de Rivoli, with all its mansions, hotels, side thoroughfares, and royal dwellings; and elsewhere, including the Place de la Bastille, the Boulevard Malesherbes, &c.; it receives, in fact, the discharge from the great sewer of the Petits-Champs, and the dangerous drain named after Richelieu, which, at the first drop of rain, is choked, and much dreaded by the workmen on account of its steep falls from the higher to the lower level. On the other or left bank of the Seine there is only one "collector," which includes, however, that which was once a pretty running water—the Biviere, which, for many years was the Fleet Ditch of Paris, famous for the abominations it poured (many-colored and fœtid) into the stream which is the pride of Paris, near the bridge of Austerlitz. This also makes an exchange with its parallels beneath the opposite bank, and, after traversing many populous neighborhoods, adds its unclean flood to the Seine.

Thus, in a space of nine or ten years, Paris is reminded it acquired, at a rough estimate, 400 miles of new or renovated drainage, constructed upon improved principles. Formerly its sewers were built of common ragstone, soft, pervious, and perishable; then, of what is called, in the vicinity of Paris, where it abounds, "millstone rock." In 1844 Roman cement was employed for the arching only; but, after 1855, the entire surface of the "gallery" was coated with hydraulic cement, ensuring a solidity and a capacity for cleanliness unprecedented. Few cases of asphyxia, we are told, now occur. The strange phenomena which, in the reign of Louis XIII., were known by the equally strange designation of "basilisks," have been driven away; overgorgings, whether of water or rubbish, are, in the main channels, so rare as hardly to be taken into account. The slopes were, in the first instance, carefully settled, though, here and there, they are in actual course of improvement; and a visit to the sewers of Paris is, in our days, equivalent to a pleasure trip—that is to say, there are certain show sections; but they must not be taken as more than an exemplification of drainage, *de luxe*, beginning with the Place du Châtelet and ending at the Madeleine. They are not, however, to be despised on that account. The gigantic hall, whence branch the grand "canals," leads to underground

roads, whence, looking up, the eye is attracted by a series of metal conduits, black and polished as ebony, which carry across this twilight highway the waters of the Ourcq and of the Seine itself; and, farther on, of the Vanne—engineering works of which the French are not unjustly proud. • Along the sides of these Titan tunnels run the tubes of the pneumatic dispatch; in the thickness of the wall are offices for clerks and lamplighters; lights enclosed within porcelain globes hang from the iron columns; there are rails and trains through the long perspective of semi-darkness. But this, as already suggested, is little in connection with the practical drainage works. A little further on, and sewage barges float upon a stream which calls up an idea of the classic Acheron. They are manned by the pilots of a singular navigation, which shuts and taps as it passes the several districts, and so in a manner regulates the general outpouring. A distinction will here be seen, broad and unmistakeable, between the London and the Paris systems, even if only mechanically considered. But, we may repeat, the subterranean Paris exhibited to visitors does not comprise all that might be shown—at least to observers of a more practical class. The attention of the Minister is drawn by the original engineer of the works that, since they were nominally completed, twelve different types of drains have been experimented upon; the grand "collector," with its broad sideways, the hollow within a hollow, leaving room for cleansing and the search after lost valuables; the drains from private houses, generally very steep in their descent towards the central "collector;" and seven or eight other varieties in form and size. As to size, it is scarcely possible to exaggerate the precautions that are necessary when a tempest of rain occurs. In July, 1872, a storm broke over Paris, accompanied by a startling fall of rain; the great running vault beneath the Rue Rivoli was, within a quarter of an hour, full; the water burst through the street gratings; many workmen were swept away; and, even now, notwithstanding the superb proportions of "subterranean Paris," five minutes' flood will imperil the city. It is by no means asserted by the memorialists that the principle of the Paris system is defective. On the contrary, they insist upon its architectural spaciousness and massiveness, its capacities of out-throw, and its power of "collecting" the superfluous waters of a storm. But the "statement"—it might be wrong to speak of it as a report—although we have used the term "sewage," really says very little concerning sewage at all. It is nearly all confined, as were the plans of M. Belgrand's engineers, to the carrying off of superfluous water. There is nothing, or scarcely anything, said to the Government about the *exuvia* of the city; yet suggestions are made vaguely in respect of this vital question, since, as the report (if so it may be termed) puts the point plainly, a system of main drainage, which is made also a plan of promenades, cannot be very practical except before being employed." But, it adds, a great advantage is gained through the power of, at any time within a few hours, shutting off and drying up a part of the extraordinary labyrinth for purposes of examination or repairs; and a special characteristic is the machinery employed—invented, indeed, since the ostentatious opening of the works—for the lifting up and disposal of such extraneous offal as masses of stable straw, hanged cats, drowned dogs, and unfeathered mattresses, the amount of which, the commissioners say, "stupefied us." Another and more tragic aspect of these vaulted highways might be alluded to, but it is unnecessary. In the parts, it is officially affirmed, which are not liable to inspection by strangers, every possible experiment is, even now, being tried, so far as regards arches of a marble unity, walls exuding and absorbing little damp, floors impermeable to any moisture except that which they carry away, and the fluted earthenware pipes, which, according to the same authority, act as final adjuncts to the rest. Another, and even a grotesque, aspect might be given to the subject by the grave reflections bestowed upon that which has generally been regarded as a ludicrous aspect of the Parisian main drainage—the rats. The sewers of Paris engender these vermin in their worst and most ferocious form, and, incredible though it may seem, they were

long under a kind of official protection for the sake of their skins, which afforded a great supply to the kid-glove-making trade of the capital, and to various other industries of that versatile metropolis, which are not yet, perhaps, sufficiently understood. This, however, at the best is only a parenthesis. It is important to know that, according to the appeal addressed to the Minister of State, the example of London is at last quoted, and that the produce of the Parisian sewers will, before long, be spread around in endeavors to further irrigate and fertilize the long-exhausted districts around.

But for the moment it suffices to appreciate the enormous and complicated works which, upon a scientific and practical representation to the French Government, it is at length proposed to complete.

THE USE OF STEEL.*

By J. BARBA, Naval Constructor at Orient.

So much remains unknown regarding the nature of steel, so much that is desirable to know and is presumably discoverable, that every new claim to fresh information on the subject of steel is regarded with interest provided the source is trustworthy.

The little work of M. Barba, just translated by Mr. Holley, bears in the names of the author and translator, sufficient guaranty of its superior value. Although the author dwells mostly upon the uses of steel in large structures, his remarks upon the nature of the metal and the classification of the grades and kind are so appropriate, and altogether interesting, that copious extracts from this part of the work will, we trust, find favor with the reader.

Mr. Holley's preface, setting forth the present condition of the steel problem, we first give almost entire.

"There are two groups of facts regarding the modern steel business, which especially concern the American manufacturers and users of this material.

1st. Three French men-of-war, built out of Bessemer and Martin steels, were so successfully constructed in 1873 that three more large ships were ordered in 1874 to be built from the same materials. Several Bessemer works in England are running exclusively on a general merchant product having a large range of grades and uses, and taking the place of both crucible steel and wrought iron. The Continental works are turning probably a third of their Bessemer product and nearly all their Martin product into other forms than rails. All the late locomotives—many hundreds—on the London and North Western Railway are built of Bessemer steel, excepting only the wheels and necessary castings. Everywhere, abroad, Bessemer and Martin steels are more and more extensively and satisfactorily employed for ship and boiler plates, beams, channels and angles for ships, bridges and other structures, railway tires and axles, general shafting, agricultural implements and the multitudinous forms of machinery bars, and forgings. In the railway and machine shops, the bridge works and ship yards of Europe and of France especially, the method of treating steel—of heating and shaping it and building it successfully into machinery and engineering structures, has become, what it must everywhere become, before this material can be employed to the best advantage, a distinct and highly developed art.

2d. In the United States, out of a Bessemer product of 350,000 tons per year, probably less than 6,000 tons are used for other purposes than rails. Very few Bessemer works have any machinery for producing the various constructive shapes required, or any experience in making steel of high or low grades. Bessemer manufacturers are talking about reducing products, in the fear that rail orders

* "The Use of Steel for Constructive Purposes; Method of Working, Applying and Testing Plates and Bars." By J. Barba, Chief Naval Constructor at l'Orient. Translated from the French, by Alex. J. Holley, C. E. New York: D. Van Nostrand.

will fall below the capacity of their works. Martin steel is now made in American works, regularly and successfully, of all grades, from springs down to boiler plates, thus furnishing every constructive grade required. Engineers and machinists are generally asking for just such material as steel has proved to be abroad, but are yet hesitating about the use of steel, because our Bessemer manufacturers have not got much into the way of making other grades than rail steel, and Martin manufacturers have not until quite recently begun to adopt those improvements in plant and practice which will make steel cheaply ; and also because our artisans have not in most cases made any study of the art of working steel, and are therefore afraid of it. Experts say that the use of wood, not only in ocean vessels, but in river and lake boats and barges, must soon give way to the use of metal, as it has done abroad and is beginning to do here; and there are thousands of wooden bridges on our railways and highways which must soon be replaced by metal ; so that for these two large uses, not to speak of general machine construction, there is growing up a vast market for a better material than iron. Excellent pig for the production of cheap steel is obtainable in all parts of the country, and ferro-manganese, upon which important qualities of constructive steel depend, is now cheap enough to warrant its general use.

In short, with every facility for making the products so largely needed here, and so largely used abroad—with the best steel works in the world, and working organizations in them which have increased product and decreased cost in a remarkable degree, we are devoting more concentrated action to schemes for preventing over production than we are to adapting grades and shapes of product to the various constructive uses, and to teaching artisans how to heat, shape and apply them.

In view of this state of affairs, it seems to me that the dissemination among our steel makers and users, of the facts contained in M. Barba's little book, should be of great advantage, 1st, to our engineers and machinists, by making more conspicuous the nature of steel and of the new and important art of working steel ; 2d, to the managers and owners of large enterprises in construction and transportation, by revealing to them the fact that steel is such a tractable and valuable material ; and 3d, to our steel makers, by showing them that a vast want exists for products which they *can* make, and what kind of steel and treatment of steel will enable them to take advantage of this existing want.

It is to be regretted that M. Barba did not give us the analyses of the steels employed—not even their percentages of carbon. This addition would have made his work complete. But by comparing the tensile resistance and elongations of the steels he mentions, with those of other steels from the same works and with Belgian steels, of which I have analyses and mechanical tests, I judge the materials put into these French ships to have had between 0.25 and 0.33 per cent. of carbon. These or even lower steels can be readily and uniformly produced in our Bessemer works, while Martin steel can be made as low as 0.10 carbon without difficulty.

It is very interesting and important to note that steels which harden and temper as readily as these do, and which hence so readily acquire dangerous internal strains, can be made so completely tractable and can be so insured against fracture in manufacture and use, by proper manipulation and by heating at the right times—additions to the ordinary iron-working processes, which are not so very costly when works are once fitted out with suitable apparatus.

Another important fact demonstrated at the Barrow works in England (set forth by Mr. Josiah T. Smith, in a late paper before the Inst. of Civil Engineers), and most completely proved by these French experiments, is that the injury done to steels of rail grade and below, by cold punching, is confined to the skin of the hole ($\frac{1}{100}$ inch thick in this case) ; and that this injury is only hardening by pressure which may be completely removed by tempering or annealing, or by reaming out this thin ring of hardened metal. The manner in which this was proved, is a commentary on the nicety of French experimenting.

It has not probably occurred to many boiler-makers who could do nothing with these grades of steel, and so have con-

demned steel altogether, that shearing and locally hammering plates put them in a condition similar to that produced by cold punching, which reduces the strength of the parts most affected, above 20 per cent. Nor has it perhaps occurred to engineers who believe in steel and are anxious to give it a fair chance, to dispense with that class of smiths and boiler makers who cannot be told anything about the treatment of steel, and will not yield to any new requirements —just as these French engineers turned out the skilled workmen who could not treat plates and bars without cracking them, and substituted carpenters, who being willing to follow instructions, made a success from the start.

The adaptability of steel to constructive purposes is specially shown in stamped work, such as pieces shaped like a low-crowned hat, of which 700 were produced without losing one, while not one good piece could be stamped out of iron. The facts that steel crystallizes less than iron by heating without working, and that steel plates have practically the same strength with, and across the "grain," are greatly in its favor.

The hardening of beams and angles of comparatively uniform section, in the last passes of the rolls, is demonstrated, and this should be a rebuke to those engineers who insist that a rail is as unlikely to break when it has a very thin flange which must come out of the rolls at a dark red heat, as if it had a thicker flange which would finish hotter.

The manner in which carbon exists in steel—in solution and in mechanical mixture—also the hardening effects of suddenly cooling steel and of cold hammering, shearing and punching, viz., hardening due to pressure; also the solution and dissemination of carbon by heat, are fully treated in this work, and will doubtless make clear a subject which in many practical minds has been more or less indefinite if not mysterious.

The more important conclusions as to treatment, to which the author comes, and to which the artisan in steel will have to come, and which are also set forth by Mr. Krupp and other steel makers who have pushed their wonderful products against the tide of "practical" conservatism into vast constructive uses, are:

1st. Avoid local pressures in working cold steel.

2d. If local pressures must occur, remove their effects by annealing—not once, but as often as dangerous pressures are produced.

The rationale of this treatment is obvious; steel is more dense than iron, hence it must be more humored in its cold treatment. But when it once gets into working shapes without internal strains, it is much stronger and safer than iron.

It should seem that such careful, thorough and obviously trustworthy experiments as those detailed in this book, and the conclusions to which they inevitably give rise, should prove a stimulus to our steel makers, to enlarge the range of manufacture rather than to curtail production because their one specialty may possibly exceed the present demand—and to engineers and to constructors of government works, to take a leading part in all efforts to adapt the new material and its treatment, rather than to wish them well from afar off."

Thus far Mr. Holley presents the question.

The French author discourses at length upon the "Composition of Steel," and upon the "Classification of Steels," in separate chapters, from both of which we herewith present liberal extracts:

COMPOSITION OF STEEL—ITS CHIEF PROPERTIES—TEMPERING AND ANNEALING.

The metals designated in the trade as cast iron and steel owe their characteristic properties to the presence of a certain quantity of carbon either mechanically mixed or in solution with the iron. These metals may contain other substances more or less affecting these properties; chiefly phosphorus, silicon, sulphur and manganese. But neither of these substances is necessary to the constitution of cast iron or steel. It is sufficient to mention that they are present in most of the irons of commerce, without studying the considerable influence they may exert.

Putting aside, then, all considerations relating to the presence of foreign matters, cast irons and steels are carburized irons. Carbon exists in them either in a state of solution or of mixture, without forming any clearly defined carburet.

"Steel is a solidified solution of carbon in chemically pure iron. This solution in a liquid state is not saturated except in case of the steel which contains the maximum of carbon which iron can hold in solution. Cast iron is a saturated solution of carbon in iron, with an excess of carbon in a state of mehanical mixture. It might be defined as steel containing carbon in mechanical mixture. In this state (mixture) the amount of carbon is larger, in proportion as that held in solution is smaller, or as the total quantity of carbon contained is greater. So gray cast iron is a slightly carburized steel with much carbon mixed, and white cast iron is a more carburized steel with less mixed carbon."

The phenomena of the solution of carbon in iron to form steel, group themselves around the four following principal laws:

1. The quantity of carbon iron can contain in solution is greater as the temperature increases.

2. By slow cooling, part of the carbon is separated from the solution and remains in a state of mixture.

3. By rapid cooling or by a sufficient external pressure, the greater part of the carbon is maintained in solution. Rapid cooling acts in this case by the pressure resulting from it. If the carbon is mixed, an external pressure produces a solution in greater or less proportion according to its intensity.

4. The temperature at which melted steel is solidified decreases in proportion to its richness in carbon.

These laws of the solution of carbon in iron conform to those which regulate the solubility of solids and gases in liquids.

1st. The solubility of solids generally increases with the temperature.

2d. When a solution made at a high temperature is cooled, part of the solid is separated.

3d. The solution would probably maintain itself under a sufficient pressure; but no experiment has been made on this subject, to my knowledge; a trial, to verify this point, would probably be very difficult of execution, on account of the enormous pressure required. The solubility of gases increases with the pressure.

4th. Finally, solutions are generally solidified at temperatures decreasing as the solutions become more intense.

The rapid and slow cooling of heated steel constitute tempering and annealing, two operations which play an important part in the use of the material.

When any metal is tempered, that is to say, rapidly cooled, the external layer cools first, and it does this all the quicker as the difference in temperature between the body and the liquid in which it is immersed is greater. The conducting power of the liquid used has also a great influence on the rapidity of cooling: tempering in mercury, for instance, will be more intense than tempering in water.

This cooled external layer contracts and presses strongly on the inside, which is yet at a high temperature; reciprocally, it receives from the inside the same pressure. Another phenomenon is a consequence of this contraction; in order to contain the internal volume, the external layers must stretch at the expense of their elasticity; if the tempering has been intense enough they may exceed their limit of elasticity and stretch permanently. If tempering has been incomplete or slight, this limit not being reached, the extension will be but momentary, and will disappear when cooling is complete.

It is known that these phenomena are practically taken advantage of, to break cast iron blocks, which could not be easily effected by blows; they are heated red and cooled in a stream of water. The external surface contracts and passes its elastic limit; as it is capable of only slight stretching before breaking; cracks show themselves on the surface, and a comparatively light blow is sufficient to break the block into several pieces.

During the second period of tempering, the cooling spreads to the centre. In their turn, the central fibres contract on account of the lower temperature; but they are bound to the external fibres which have exceeded their limit of elasticity; they must then stretch at the expense of their elasticity as they contract; they, at the same time, cause a contraction of the external fibres.

A tempered body is therefore subjected to direct forces which are balanced by molecular tensions. The forces which exist after tempering can be ex-

hibited by suppressing a part of them. If a bar of tempered iron, squared on all sides, is cut in two longitudinally in a planer, care being taken to hold it in an invariable position, each of the pieces assumes, when left to itself, a curved form, the concavity of which is on the planed side. This form demonstrates a tension in this part, resulting from the second period of tempering. The forces brought into play in the first period would have produced the opposite effect if they alone had acted.

Bodies increase in volume when they are tempered. M. Caron has observed the following variations of steel bars :

TABLE No. I.

	Natural state.	At Red Heat.	After tempering.
Length.....	20.00	20.32	19.95
Width.....	1.00	1.03	1.01
Thickness...	1.00	1.03	1.01
Volume.....	20.00	20.00	20.351

In these bars the length decreased and the width and thickness increased ; under the influence of an internal pressure the bar behaves like any homogeneous body subjected to deformation by an internal force ; it tends to assume the spherical form.

M. Caron mentions another instance of a bar of rolled steel :

TABLE No. II.

	Natural state.	After Tempering.
Length.....	20.00	20.45
Width.....	1.51	1.51
Thickness.	3.70	3.70
Volume...	111.74	114 25

In this example tempering has again produced an increase of volume ; but unlike the preceding case, the greatest dimension has increased and the others have not changed. This contradiction is apparent only. It is explained by the lack of homogeneity in a rolled bar which is capable of stretching more readily in the direction of the rolling, than perpendicularly to it. The longitudinal fibres exceed their elastic limit before this limit is attained transversely ; the addition to the volume consists in increased length.

Tempering should produce these effects in homogeneous bodies only, the composition of which does not vary with temperature and pressure. In steels and other carburized irons tempering is complicated by the presence of carbon, the solution of which it partly brings about. It is difficult to know whether the increase in volume observed in tempered steel is to a certain extent modified by this solution ; by continuing the comparison between the laws of solubility of solids in liquids, we may suppose that the increase in volume does not result from this cause ; for a solution never has a larger volume than the total volume of the bodies it contains.

The solution brought about by tempering steel produces a body endowed with properties different from those it possessed before tempering ; but this body, at the time of sudden cooling, is always under the influence of the phenomena we have just explained. The pressure resulting from the two phases of tempering maintains in solution a part of the carbon that would have become separated by slow cooling ; this portion will be greater as the pressure is stronger, and the tempering more rapid.

If a non-homogeneous body is tempered, composed for instance of steels at different degrees of carburization, the action will be complex ; it seems probable that, when the body is hot, the carbon will be distributed a little less irregularly, and that this dissemination can increase only under the pressure of the cooled external fibres. If we suppose this body represented by different tints according to its amounts of carbon in different parts, the lines of demarcation, instead of being decided as in the original state, will be blended after tempering.

This phenomenon of transfusion of carbon through iron or steel heated to a sufficient temperature is well known. A bar heated with charcoal is cemented, or dissolves carbon first on the surface, then more deeply, and finally to the centre, if cementation lasts long enough.

When steel is subjected to different degrees of tempering, the carbon is kept in solution in a much larger proportion, as tempering is more energetic. With each class of steel, there should correspond a degree of temper at which the maximum effect is produced, that is to say, when tempering would cause the solution of all the carbon contained in the steel. If the effort of contraction were the same for all steels, the intensity of temper producing this effect should increase with the degree of carburization. But the contraction or pressure due to rapid cooling is generally insufficient to produce this result. The more the rapidity of cooling is increased, the more the steel changes its properties. The least carburized steels only could be excepted; beyond a certain point the solving effect produced by an increase of intensity in tempering ought to be nothing; alternations in elasticity only could be observed. But, in these bodies, the limit of elasticity is reached under relatively slight effects, and tempering, by a variation of temperature such as we can effect, does not produce a sufficient pressure to dissolve all the carbon

Tempered bodies generally regain their properties when they are annealed, that is to say, when they are made to cool slowly after having been heated sufficiently. When a homogeneous body, the composition of which does not vary by heating, is annealed, the effect is merely to restore its original elasticity. To insure thorough annealing, the operation must be performed at a sufficiently high temperature, and the cooling must be slower as the size of the body is greater, so that there may be between the interior and exterior, but a slight difference in temperature. The first condition is necessary to allow the metal to recover the elasticity it lost in tempering; the second condition should prevent in the successive phases of cooling, the production of undue strains.

In complex bodies like steel, the effect of annealing is complex; besides this restitution of elasticity to the fibres altered by tempering, it produces the separation of a part of the mixed carbon. This separation must take place equally throughout the mass to render the bodies homogeneous after annealing; and it is easily understood that a very slow cooling is necessary to insure this result. For large pieces of steel, this cooling must occupy several days, sometimes several weeks.

When steel is properly annealed, the different molecular tensions previously produced are suppressed; the fibres relax under the influence of heat, and return to their first elasticity.

If annealing is applied to a piece having undergone local tempering, the effect will be the same. In a bar made up of steels of different degrees of carburization, annealing will establish a little more homogeneity. Owing to the high temperature the bar will have to bear, the lines of demarcation will no longer be as clearly defined, and the difference between the several parts will be less, as the piece is exposed longer to the fire. In annealing, this more regular dissemination of carbon is due only to the high temperature to which the piece is raised, while in tempering, the effect is increased by the pressure resulting from rapid cooling.

Annealing must not be performed at too high a temperature,—near the melting point,—less the fibrous texture of the metal acquired by forging, should be changed; slow cooling would crystallize it, and it would then have no elasticity,—it would be burned.

In the same steel there may exist a series of intermediate states between the natural state and the state corresponding to the maximum temper it can take. The several properties of the same steel follow a continuous law of variation between these two extreme points. In the natural state, steel possesses a hardness increasing as it contains more carbon and as it approaches more and more the maximum of saturation. Tenacity, or resistance to breaking follows the same law, increasing in a continuous manner from soft iron to the hardest steel.

The stresses steel can bear before reaching its limit of elasticity follow the same law. On the contrary, the attainable stretching increases when the quantity of carbon and consequently the hardness and tenacity increase. The welding properties vary like the stretching qualities; they are very high in slightly carburized irons, and are reduc-

ed to almost nothing in steels rich in carbon.

When steels are tempered under the same conditions, hardness, tenacity and stretching follow the same law that obtains in the natural state ; hardness and tenacity increase with temper, and ductility decreases. In short, the difference between a steel in the natural state and the same steel tempered is less as carbon decreases and as the metal approaches pure iron.

We will consider here, only temper obtained by rapidly cooling steel heated to a high heat in a cold liquid. Under these conditions the changes of constitution induced by tempering should decrease as the operation is performed on less carburized steels. With very high steels, the elastic limit is reached under a very heavy load only ; with soft steels the elastic limit is much more quickly attained ; the same degree of cooling will then produce a contraction and pressure much smaller in the second case than in the first.

From this statement we may conclude that, whenever hardness and tenacity are required, and a material liable to deformation before breaking is not desirable, the highest or most carburized steel must be used ; from this class is chosen the steel for tools that are not worked under blows. For constructive purposes where a more elastic material is needed, less carburized iron, in other words, soft steel must be used.

We can conceive that tempering followed by annealing might be used to improve certain more or less carburized iron, especially to restore homogeneity lost in the different stages of manufacture. All merchant irons contain slight quantities of carbon, and consequently yield, but in a less degree, to the influences of tempering and annealing. Heat produces in iron, a more complete solution of the carbon and a dissemination of that mixed in the metal ; probably also of other foreign ingredients. The pressure which follows tempering increases this dissemination. Finally, while annealing, the heat continues the effect produced, and slow cooling allows the molecules to group themselves so as to nearly remove the several internal strains.

In a great many cases tempering is followed by such an incomplete annealing as tends to lessen the molecular tensions, while preserving in the metal the greater part of the properties due to tempering, viz., hardness, tenacity, and also a more homogeneous composition. Afterwards more or less annealing is given according to the degree of elasticity which is to be restored.

Partial annealing after tempering is used in armor plates. The tempering they undergo after rolling renders them more homogeneous throughout their mass, by the compression it produces in every direction. Hardness, or resistance to the penetration of projectiles is increased, but the metal becomes brittle, as the tempering is more complete, or, with the same range of temperature, as the plates are thicker.

Complete annealing would destroy all brittleness ; but in order to preserve some hardness and prevent any internal crystallization, annealing is carried only to dark red ; this temperature is insufficient to restore to the different fibres, all their elastic properties, but it allows a preservation of the greater part of the hardness proceeding from tempering.

In plates measuring less than 20 centimetres (.787 in.) in thickness, this annealing is sufficient for the purpose mentioned ; the result is a metal able to withstand the penetration of projectiles and rarely breaking under their impact. In thicker plates submitted to tempering and annealing under the same conditions, the molecular tensions after tempering preserve more value after annealing; the places satisfactorily resist penetration; they, however, have considerable brittleness. To avoid this defect, it would be necessary to give more intensity to annealing; the plates would then offer less resistance to penetration, but they would no longer break under blows.

The same result ought to be attained by reducing the intensity of temper; the heat to which the plates have to be raised cannot be lessened, since, in order to obtain homogeneity, a solution of all foreign matters in the iron must be produced ; but the rapidity of cooling can be diminished by using a liquid which is a less good conductor than water, or by raising the temperature of this water. By this latter means the heated piece will be subjected at first to a rapid cool-

ing to prevent separation of the carbon from its solution, then a much slower one, to prevent extreme molecular tensions.

These considerations are verified by M. Caron's recent researches. In laboratory experiments he has succeeded in bringing to the same degree of hardness, tenacity and elasticity, some steel springs tempered and annealed by the ordinary process, and others simply tempered in hot water. He expresses himself as follows, upon his experiments:

"Tempering in hot, or rather boiling water singularly modifies soft steel containing from $\frac{1}{1000}$ to $\frac{1}{1000}$ of carbon; it increases its tenacity and its elasticity without sensibly altering its mildness."

M. Caron, in experiments reported in the same article, succeeded in regenerating burned iron by tempering it in a hot liquid; he used a solution of sea salt heated to 110 degrees centigrade. The primitive texture is then restored to the metal by the strong pressure due to tempering and the drawing out of the fibres which results from it. The slow cooling following this first effect, allows the fibres to recover the greater part of their elastic properties, notwithstanding the previous rapid cooling. It is well known that burned iron is restored by raising it to a white heat and submitting it to an energetic hammering. It will be seen that tempering acts the same as hammering; it constitutes a real forging action, producing a drawing out of the metal. It follows from this that the quality of cast ingots might be improved by a series of temperings which would bring them to the same state as if they had undergone a preliminary forging or rolling. We have not been able to verify this deduction, not having steel ingots at our disposal.

CLASSIFICATION OF STEELS—SOFT STEELS USED AT L'ORIENT AND BREST—TESTS.

The various properties of steels—their resistance, their stretching, the manner in which they are affected by tempering—furnish a convenient way of comparing and classifying these metals; it would be difficult to do so, practically, by taking their composition as a basis.

Until a few years ago, steels more carburized, and much more liable to the defects pointed out above, than the very soft metal now manufactured, were generally used. The substitution of ferro-manganese for spiegel, to produce carburization at the end of the Bessemer process, or in the Siemens-Martin furnace, has contributed to the production of materials containing very small quantities of carbon, though free from the oxydes of iron that the manganese was designed to reduce or remove. To distinguish this steel from the one they had previously put in the market, the manufacturers have given it the name of *métal fondu*, or *cast metal.*

The steel used in France and England in building large ships may always be classified among soft steels; but France alone has so far, we believe, worked cast-metal on a large scale.

The constructors of the English navy demanded for their steel plates a tensile resistance of 32.9 tons per square inch in the direction of the fibre, and 29.8 tons perpendicularly to the fibre.

The resistance should in no case exceed 39.9 tons per square inch.

For the ships built at L'Orient and Brest, where cast metal alone has been used, the minimum tensile resistance required was 28.5 tons per square inch, with a corresponding stretching of 20 per cent. at least. For deck beams made up of I bars, $11\frac{13}{16}$ in. deep, the lowest limit of stretching was put down to 18 per cent. in consideration of the difficulties of manufacture. The plates were furnished in nearly equal quantities by the works at Creusot and at Terre-Noire. The I beams were manufactured by MM. Marrel Bros. of River de Gier from Terre-Noire steel; the other rolled bars and beams were furnished by the Creusot works.

The steels were manufactured at Terre-Noire by the Bessemer process, and at Creusot by the Siemens-Martin process. Both these great works have succeeded by means of numerous tests, and the certainty of their manufacture, in furnishing soft steels of obviously even quality. They can, however, vary, at the wish of the buyer, the properties of their products. The bars subjected to test were all turned to 3.93 in. in length, the section being 0.31 square in. Tempering was done in oil, the bars being heated as unformly as possible to a temperature corresponding to bright red.

The steel furnished to the Government works at L'Orient and Brest, offering a minimum tensile resistance of 28.5 tons per square inch was to reach its limit of elasticity only under a heavier load than 13.94 tons. Estimating that iron plates reach this limit of elasticity under a load of 10.4 tons per square inch., which is rather above the average, it will be found that, in construction, an iron plate of thickness e' can be replaced by a plate of thickness e' determined by the relation :

$$22\ e' = 16.5\ e, \text{ or } e' = \tfrac{3}{4}\ e.$$

This is the case only when the plates suffer a direct tensile strain. An iron plate 0.47 inch thick can then be replaced by a steel plate 0.35 inch thick.

At L'Orient, all the tensile tests on Creusot or Terre-Noire steel were made with a scale built by M. Frey, having a

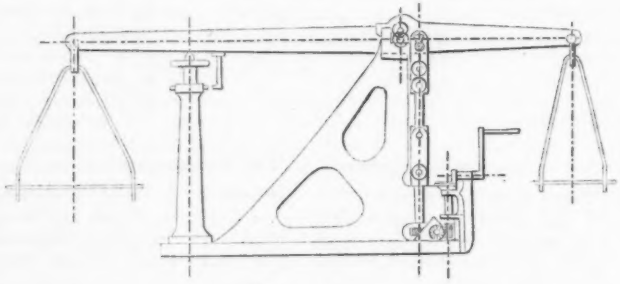


FIG. 1.

Scale for Measurement of Tensile Strains.

range of 0 to 25 tons (Fig. 1). The test bars, a sketch of which is given in

FIG. 2.—Test Bar.

Fig. 2, were brought to a uniform section for a length of more than $7\frac{7}{8}$ inch. Each end was wider than the body, and these different widths were connected by easy curves. In the outline, great care was taken to avoid any angle in which a rupture might originate. At each end holes were drilled allowing the bars to be connected to the jaws of the testing-machine by heavy pins. The beam of the scale was always kept horizontal for this purpose, the lower fixed point of the bar was moved down while the stretching was taking place. The tensile strains were obtained by loading successively one or the other scale beam ; they were gradually increased, 44 lbs. at a time, leaving a certain interval of time between each increment of load to give to the successive elongations time to develop themselves.

To ascertain the limit of elongation a length of 7 in. was defined by two centre punch-holes ; on these marks were fixed the extremities of a small apparatus (Fig. 3) ; this apparatus was frequently applied, and indicated by its graduation the successive elongations. An observer followed the travel of the index, and noted after each rupture, the figure given by the instrument, also the load put on the scales. These tests were always made by the same men.

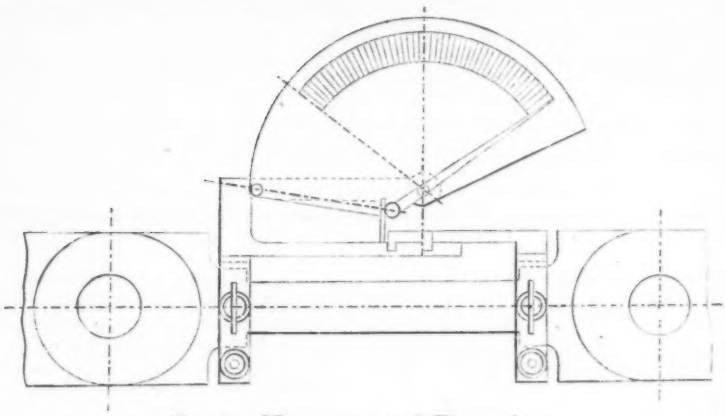


FIG. 3.—Measurement of Elongation.

Besides these tests of tension, the toughness of the metal was frequently ascertained by bending strips cut from plates or bars; this was done by hammering only on the extremities of the specimens and never where flexion was taking place; the bending was stopped when the first crack appeared and the results obtained were noted and kept as a basis of comparison. Sometimes the bending was done under a hydraulic press, thus allowing work without blows; the specimens so tried gave the same curves as those bent by the hammer under the conditions just described.

The Steels from Creusot and Terre-Noire subjected to these different tests did not give the same results; it was therefore important to repeat them, in order to determine the relative value of the products.

The grain of the metal (as shown by fracture) indicated at first sight, a slight difference; in order to examine it, nicks were made in plates and beams with a chisel; the use of a sledge was avoided, as it might have altered the grain; the specimens were then broken as usual by bending. The Bessemer metal showed a very fine grained break, slightly slate colored, and approaching the fracture of steel proper; by tempering, the grain became still finer, the color or brightness not varying sensibly. In I beams, the grain was a little more steely than in the plates. The Martin metal from Creusot gave a finer grained fracture, whiter and brighter; it approached more by its brightness and color the fracture of fibrous iron; tempering did not modify it in a very appreciable manner. In every case the grain evinced the greatest homogeneity, at every part of its surface.

Some strips were cut on a planer from plates from both makers; the mean deformations (Fig. 4) were obtained on a series of Bessemer plates, and (Fig. 5) on a series of Martin plates.

4.—Bessemer. Natural State. 5.—Martin. Natural State. 6.—Bessemer. Tempered.

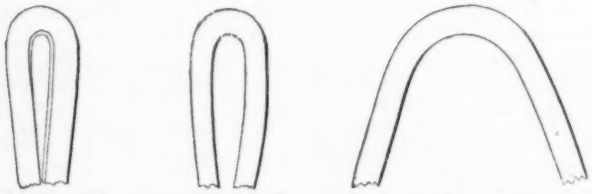
Figs. 6 and 7 give the mean deformations obtained after tempering, and Figs. 8 and 9 after tempering and annealing.

7.—Martin. Tempered. 8.—Bessemer. Tempered and annealed. 9.—Martin. Tempered and annealed.

Tempering was done by heating the plates to cherry-red and dipping them into water at 50° Fahr. Annealing was obtained by heating to cherry-red. These experiments were made on specimens 0.31 inch thick for Bessemer metal and 0.35 inch thick for Martin metal; the trial was consequently a little harder for the latter.

Martin steel bore the bending test in the natural state, a little better than Bessemer steel; the difference was slight, but very decided after tempering, and we notice from this stand-point a marked inferiority in the products from Terre-Noire. Finally, after annealing, elasticity was obviously restored to what it was before tempering.

Strips cut out of I beams gave in the natural state, the average deformations, Fig. 10, when cut from the flange, 0.53 inch thick on the average, and Fig. 11



10.—Fers en H. (Flanges, Natural State.) 11.—Fers en H. (Web, Natural State.) 12.—Fers en H. (Flanges, Tempered.)

when cut from the web, 0.42 inch thick. After tempering, cracks were observed when the specimens were of the form Fig. 12 for the first, and Fig. 13 for the

13.—I beam, Web Tempered.

others. The I beam metal, chiefly in the region of the web, seems to experience by tempering an alteration in elasticity much more prominent than that observable in Bessemer plates under similar circumstances.

Two series of tensile tests made on plates, angles, and I beams gave the following average results:

TABLE IV.

Untempered Steel.

	Resistance to Rupture per sq. inch of the original section.	Per cent. of Stretching.
Bessemer Plates....	31.60	20.2
Bessemer I Beams..	32.81	19.5
Martin Plates.....	28.69	24.1
Martin Angles.....	29.00	21.7

A few more tensile tests after tempering were made at L'Orient. Tempering was done in the manner described above for the trial strips.

The result was as follows:

TABLE V.

	Resistance to Rupture in tons per square inch of the original section.		Per cent. of Stretching.	
	Lengthwise.	Crosswise.	Lengthwise.	Crosswise.
Bessemer Plates	30.95	30.83	22.9	21.9
Martin Plates	29.88	30.07	24.2	23.5
Bessemer I Beams	33.39		21.1	
Martin Angles	30.45		24.5	

TABLE VI.

	Resistance to Rupture in tons per sq. inch of the original section.	Per cent. of Stretching.
Bessemer Plates	44.22	
Bessemer I Beams	47.69	6.4
Martin Plates	34.58	

A few more tensile tests were made after tempering and annealing. It was observed that annealing, well done, restored to the metal in every case its previous tenacity and elasticity, as modified by tempering.

Finally, by trying these different products with a file, it was noticed that the I beams were the hardest to cut; then came the Terre-Noire plates; the Creusot plates and angles were obviously softer than the preceding. After tempering hardness could be classified in the same order.

We may then conclude from these different experiments that Terre-Noire steels have more resistance to rupture, more hardness and less elasticity than the Creusot products; they are much more modified by tempering; in short they evince the characteristics of more carburized iron. Moreover, the rolled beams seem a little more steely than the plates from the same origin. It is hard to explain this fact, without knowing all the circumstances attending manufacture. It may be that the plates undergo in the heating furnace a more decided decarburization than the beams; the thin plates present in the last heatings, with the same volume, a larger surface to the action of flames that may be slightly oxydizing.

The remaining chapters of this valuable treatise relates chiefly to the more technical matters of treatment of plates, beams and angle bars, both in manufacturing and in the processes of punching, drilling, riveting, &c., during the progress of their employment in building. We must leave these chapters for another occasion.

ON RIVER GAUGING AND THE DOUBLE FLOAT.

BY S. W. ROBINSON, Professor of Mechanical Engineering in the Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

IN the October number of the Magazine will be noticed an article by Gen. H. L. Abbot on the "Hydraulic Double Float," in which numerous references are made to my paper on "River Gauging and the Double Float," which appeared in the August number. I feel called upon to make mention of the General's article for two reasons: 1st, because I feel highly complimented by its receiving attention from one so distinguished as he, and hence should return my willing tribute of thanks; and 2d, to correct the impressions which his remarks may

have induced, in regard to a few points in my article.

The facts brought out by my investigations, given in the article referred to, I think I stated in as mild terms as consistent with the facts themselves; and without aiming to detract, in the least, from the real value of the very important work reported upon in the "Physics and Hydraulics of the Mississippi River," because I consider the work and the report as exceedingly complimentary to its authors, as well as a most valuable treatise on River Hydraulics. The discovery that the mid-depth velocity is unaffected by wind currents, I regard as of great importance and value; and which, alone, is worthy of the issue of a book. But having found, by my investigations, that a correction should be applied to double float observations whenever, and wherever made with a large connecting cord in use, in order that the observations be reduced thoroughly in keeping with science, I felt prevailed upon, on account of the great labor involved, to make it public, with a view to aiding such as may desire to use the double float, or to study observations made with it.

The General sets out by saying that he will correct a few misapprehensions into which I have fallen; the most important one, as appears from his remarks, being the "entire inapplicability to the Mississippi River, of the equations." In reply to this I must say, with all due regard, however, for the General's honesty in defending his supposed faultless reduction of the Mississippi observations, that I did not in the least misapprehend the matter; that it was in studying the results of the float observations of the Mississippi itself that I became convinced that when a large connecting filament is used between the floats, the resulting observed velocity should be corrected; that on completing my formulas I found, by applying them to the Mississippi observations, they gave a correction; that, at the time of publishing my article, I had not applied them to any other observations; and as there appears to be no good reason why the formulas should not apply with equal force to the double float when used in Mississippi River water, as well as in the water of any other river, "we are not left in doubt as to their entire" *applicability* to the Mississippi observations.

I must contend that I have *proved*, not merely stated, to any one who has carefully looked over my article, that the best and most truthful results, obtainable from double float observations, can only be realized by including, among others, the needed correction for the connecting cord, and this proof I cannot give up for a statement only. When, for instance, as pointed out in the article, four-sevenths of the actual float area, presented to river current, is made up of the cord itself, every part of which, for great proportional depths, is in swifter water than the lower float. How can there remain a trace of a doubt of at least some slight resulting influence acting to hurry along the float combination? That the float velocity should be materially modified by the presence of a large connecting cord, in an instance like the above, is so self-evident, even were it unsupported by vigorous analytical proof, that the description of the bobbing flag is insufficient to effect the burden of proof without accompanying figures showing the *unmistakable* and *exact* position of float, the *precise* depth of river at the very point, and the length of float to its *extreme bottom;* and even then, if one or the other *must* be doubted, can it be otherwise than the figures defining the conditions of the float as to proximity to bottom, rather than the entire absence of action of the current upon more than half of the float area?

Again, if a cord nearly a quarter of an inch in diameter is ever necessary, as represented by the General to have been on the Mississippi, it may be safely employed by simply providing for its errors. This may be done by an empirical method as well as by analysis. But the fact that it is necessary can, it is plainly evident, be no guaranty that the current will not act upon it, nor that it will be exempt from correction.

The criticism in regard to neglecting the masses of the floats, if it applies, must be with respect to a correction which I made no attempt to elucidate; and, hence, another error which the Mississippi observations are subject to. The observations which I treated were supposed corrected for all errors except that due to the large cord and upper float.

Also, if the pulsations and whorls exist, their action upon the cord would crook it into unaccountable curves, every one of which would shorten the distance between the floats, and prevent contact with river bottom; and, hence, an argument by the General himself against his own theory of touching of bottom by lower float, and consequent oscillation of upper float and flag. If, therefore, my formulas err at all, they err on the side of giving too few corrections, instead of erring on the side of "entire inapplicability to the Mississippi River."

The modern watch or clock needs regulating that it indicate correctly, so the meter needs its coefficient of velocity. But who, at the present day, would throw away his watch or clock in preference for the sundial, because the latter needs no coefficient of velocity?

Also, the General makes the statement with considerable force that Gen. Ellis finds the float and meter to "give sensibly the same result," an argument of his own in favor of the meter. Again, just before that, he says that the efforts to determine the curve of velocities "utterly failed" till the double float was used. But why should the meter have failed if it gives sensibly the same result as the float?

In my article, my formulas were only applied to observations taken in the Mississippi River, where a large connecting cord was used. To show how the errors disappear when a fine wire is used, agreeably to the requirements indicated in the discussion of my formulas, I have computed some of the corrections for the float observations, made by Gen. Abbot himself in a feeder of the Chesapeake and Ohio Canal, and given on page 253 of the Mississippi Report, where the upper float presented an area of a quarter of a square inch, and the lower float 17 square inches, the floats being connected with a "very fine wire." Depth of canal, seven and a tenth feet; W estimated at 0.005 lb., $C_1=0.75$, $C_2=1.75$. Using data as given, I find

For $y=5$ ft.	$x=.08$ ft.	$v_2-v_1=.043$
" 6	" .39 "	" .061

which show no appreciable rising of the lower float on account of its falling behind the upper, and corrections only about a tenth of those found where the large cord was used, which indicate a decided advantage in use of wire if the observations are to go uncorrected.

Permit me to remark, finally, that I see no cause for altering either my analysis or results of the same, on account of the interesting additional particulars regarding the Delta Survey, which Gen. Abbot has so kindly given in his article.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The twenty-third annual meeting of this Association was held on Wednesday last.

The annual report of the Board of Direction upon the affairs of the Society was read, from which it appears that the increase in membership during the year was 48, and the present number is 492. By donation and purchase, there were added to the Library about 850 books and pamphlets, many photographs and other illustrations of engineering structures. The treasurer's report shows the finances of the Society to be in satisfactory condition; the increase in receipts keeping pace with increased expenditures during the year incident to change in location of the Society rooms.

Officers were elected as follows:

George S. Greene, President.
Theodore G. Ellis, } Vice-Presidents.
W. Milnor Roberts, }
Gabriel Leverich, Secretary.
John Bogart, Treasurer.

Octave Chaunte, Alexander L. Holley, Francis Collingwood, Quincy A. Gillmore, and Julius W. Adams, Directors.

Subsequently the Standing Committees were appointed as follows:

On Finance—Messrs. Roberts, Gillmore and Collingwood.

On Library—Messrs. Holley, Bogart and Ellis.

The Norman Medal was awarded for a paper "Description and Results of Hydraulic Experiments with large Apertures at Holyoke, Mass., in 1874," by Gen. Theodore G. Ellis.

Reports of Committees on "Tests of American Iron and Steel;" "Time and Place of the Eighth Annual Convention;" "Mutual Benefit Society;" and on "Policy of the Society," were adopted. It was determined to hold the next Annual Convention at Philadelphia, June 13th—15th, 1876. The matter of presenting American Engineering at the Centennial was referred to a Committee. A proposition that action be taken towards adopting the metric system of weights and measures was discussed; and amendments to the By-Laws relating to the appointment of Committees to report on professional topics or perform expert service; Annual Conventions being declared business meetings; making Past Presidents of the Society members of the Board of Direction; holding social meetings at the Society's rooms during the winter; and other matters were considered and duly referred.

The Annual Dinner was held at Delmonico's

—Gen. Theodore G. Ellis presided and informal speeches were made by Messrs. Roberts, Briggs, Holley, Bloor, Western, Thurston and others.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ON WEIGHTS AND MEASURES.—The special committee of this association, to which this subject was referred, report upon the steps taken the past year for the establishment and perpetuation of the basic units of the metric system, and the results of the conference of delegates from twenty-one nations. The United States was represented by Prof. Joseph Henry, of the Smithsonian Institute, and Julius G. Hilyard, of the Coast Survey (now President of the association). The original standard meter and kilogram were adopted, and steps taken for authentic reproduction of them for distribution, and for comparison with other standards of dimension or quantity. The report comments upon and lauds the co-operation of our executive government in this great effort for universal civilization, and asks from all scientific bodies an expression of opinion to urge upon Congress the monetary aid desirable to meet the national share of the expenses; estimating the same at $12,000 original appropriation, with about $1,000 per annum subsequently. The committee say: "It is to be considered, that this is not designed merely to advance the interests of the metric system of weights and measures, or to serve as a means of promoting the extension of that system. The design is higher than that. To secure the universal adoption of the metric system, would be undoubtedly to confer an immense and incalculable benefit upon the human race; but it would be a benefit felt mainly in the increased facilities which it would afford to commerce, and to exactness in matters that concern the practical life of humanity. On the other hand, to secure that severe accuracy in standards of measurement which transcends all the wants of ordinary business affairs, yet which, in the present advanced state of science, is the absolutely indispensable condition of higher progress, is an object of interest to the investigators of nature immensely superior to anything which contemplates only the increase of the wealth of nations. . . . . ."

A series of resolutions were offered by the committee, and were unanimously adopted by the association. Those of our readers who are interested especially in the metric system, will find this report in full in the proceedings of the association, which will shortly be published.—*Franklin Institute Journal.*

IRON AND STEEL NOTES.

MR. DAVID MUSHET states in his paper on "Iron and Steel," that 4 tons of coke was the quantity of fuel employed about the year 1810 for each ton of pig iron made in Great Britain. In Shropshire it was ascertained, about the year 1840, by Mr. William Jessop that the quantity of pig iron made amounted to 82,750 tons, consuming in its manufacture 409,000 tons of coal, or nearly 5 tons of coal to each ton of pig iron. In Great Britain, in the same year, Mr. Jessop further ascertained that the quantity of pig iron made amounted to 1,396,400 tons, consuming 4,877,000 tons of coal, or an average of 3½ tons of coal to each ton of pig iron manufactured. In July, 1867, the commissioners appointed by a Royal Commission in the previous year to inquire into the question of the probable duration of our coal-fields and their resources, began the important inquiry entrusted to them, and periodically for five years pursued their investigation. This investigation of the Coal Commission, as regards the statistical inquiry, was entrusted to the late Sir Roderick I. Murchison and Mr. Robert Hunt, Keeper of Mining Records, and forms vol. iii. of the Coal Commission Report, consisting of nearly 500 pages. The deductions drawn from this report show that in the year 1869 the quantity of coal employed in the manufacture of a ton of pig iron amounted to 3 tons in Great Britain, and the inquiries subsequently instituted by the Mining Record Office show that in Shropshire in the years 1872 and 1873, it amounted to the like quantity, while taking the average of Great Britain in the same years, 1872 and 1873, we find that 51 cwt. of coal was the quantity used in the making of each ton of pig iron.—*Engineer*

THE IRON TRADE.—The iron trade is at present passing through one of those crises which appear to arise once every six or seven years in its history. Naturally the danger is most threatening where there has been the most rapid growth and expansion—namely, in the North of England. The condition of the trade was, perhaps, never more perilous, nor required greater prudence and judgment on the part of those responsible for its welfare. Several heavy failures have occurred, and more will undoubtedly follow if the tide of doubt and suspicion which has set in be not quickly stemmed. When bankers suddenly withdraw the facilities which have for years been ungrudgingly granted to a hitherto thriving and prosperous district, the effect may be in some respects beneficial, but it may be purchased at a cost which those who produce it may find somewhat expensive.

The question is, Is the iron trade really unsound? Has it ceased to be a profitable staple, and is the present depression likely to be lasting?

It is undoubtedly a trade liable to severe alterations of adversity and prosperity, but, on the whole, it has been signally prosperous, and has advanced truly by "leaps and bounds."

In 1852 the capital embarked in the iron trade in the North of England did not exceed £300,000 and the whole manufacture of iron did not exceed a value of £500,000. In 1874 the capital employed in the trade was variously estimated at from £5,000,000 to £6,000,000 while the value of pig-iron and manufactured iron produced amounted to £15,000,000. The growth of the Middlesborough, Stockton, and Hartlepool has been one of the most remarkable features of the past quarter of a century.

Of the £6,000,000 of capital now sunk in machinery, plant, buildings, &c., fully £5,000,-

000 has been the result of untiring industry and thrift. Scarcely a moneyed man has ever come into the district, and it is a curious fact that, except two, there is not yet a gray-haired man in the iron trade in Middlesborough, Stockton, or Hartlepool.

This great growth has been several times arrested, and despairing croakers have been as prophetic of evil things to come in years past as they are at the present moment. But after a year or two of dulness there has been the invariable rebound, enduring for several years, when manufacturers have flourished, and the producing power of the district has been largely developed.

Profits have been invariably spent on additional works, and when, as happened in a recent case, bankers shut up their pockets, the struggling manufacturer has to go to the wall, although it is confessed, if his works and plant could be turned in a month's time into cash—which is impossible—he would have sufficient to pay his creditors 40s. in the pound.

In 1852 there was a general impression that pig iron, which in the early part of the year was 36s. per ton, would never see 40s. again. By the end of the year the price was 65s. per ton, all other descriptions of iron advancing in similar proportions.

In the panic of 1857 a similar state of affairs supervened.

In 1866, when all English railways fell into discredit, it was generally believed that the iron trade had passed its highest powers of demand and production, and that no good could be expected from it again. Pig-iron fell to 51s. per ton, and remained there for a long time; but in 1871 we saw it at 140s. and such a demand accompanied this price that a large stock of nearly 700,000 tons was cleared off, while production itself had made unprecedented strides.

For a year and a half the trade has been in a languishing and unprofitable state. Manufacturers have lost money, but not a fleabite of their earnings. The bad debts of merchants have, on the whole, not been serious.

When the worst has come the tide turns, and there are symptoms that the dullness which has pervaded the whole commercial world is beginning to lessen. Wherever civilization spreads iron will be in request, and there is no reason to fear either that as a great staple of this country it will be in less request or that any other country can beat us in the race of competition.

If the timidity of some and the shortsightedness of others should cause the present depression to be the cause of widespread ruin and disaster in a district which has been remarkable for its industry and integrity, it will indeed be a matter of very great regret.—*London Times.*

RAILWAY NOTES.

PARIS TRAMWAYS AND RAILWAYS.—On their next assembly, the Paris municipality are expected to apply for powers to construct a new line of tramway from Porte-Maillot to the Bridge of Suresnes, passing through the whole length of the Bois de Boulogne. Tramway extension in Paris has proceeded at a rate which seems to indicate a high appreciation of the value of the old Roman motto, *Festina lente.* The Vincennes tramway was authorized on February 10th, 1854, and opened to the public August 25th, 1875, after a delay of twenty-one years, six months and seven days. Proceedings at the present moment, however, are active enough. Since January, besides the line from the Louvre to Vincenne the Compagnie des Omnibus have began that from the Point de Boulogne to Saint-Cloud, and from la Villette to the Place de l'Etoile; while the Compagnie des tramways-nord began the lines from Courbevoie to Suresnes, from Saint-Augustin to Levallois-Perret, and from the Place Pereire to Neuilly. Three other lines are being made from la Villette to the Place du Trone, from the Place Clichy to Saint-Denis, and from the Place Saint-Germain-des-Pres to Clamart, while plans are being drawn for two others, one from the Place de l'Etoile to Saint-Augustin, and another from Courbevoie to Reuil. Railway communications between Paris and the suburbs are becoming little by little easier and more abundant, the last section, 14 kilometres long, of the short railway from Paris to Vincennes and Brie Comte-Robert, with a total length of 36 kilometres, was opened on August 5th last, the first concession for the railway bearing date August 17th, 1853. On August 7th last another suburban railway, that from Bondy to Annay, connecting the line of Soissons with that of Avricourt, was inaugurated. This connection, 8 kilometres long, will be thrown open with the least possible delay.—*Engineer.*

BRAKE EXPERIMENTS.—In consequence of a statement made by one of the principal officers of the Midland Railway Company, with reference to the collision at Kildwick, to the effect that the engine-driver of the mail train would have been able, with the means at his disposal, if traveling at the rate of fifty miles per hour, to stop his train in 400 yards, certain brake experiments were made, in the presence of Captain Tyler, on the Derby, Castle Donnington and Trent line, on the 21st ult. There were four trials. In the first of these experiments all available means were used to stop the train, viz., tender-brake and one guard's van-brake at rear of train applied, sand used, and engine reversed and steam against it, with the Le Chatelier tap open. The gradient was level; the train, the total weight of which was 102 tons 7 cwt. 2 qr., was running at the rate of 49.9 miles per hour when the brake was applied. The result was that 54 seconds were occupied in stopping the train, which, after the application of the brake, ran a distance of 807 yards. In the second experiment all available means were used except reversing the engine; gradient, 1 in 330, up and level; speed, 49.9 miles; time occupied, 60 secs.; distance run, 843 yards. In the third experiment all available means were used, and when the engine was reversed, the regulator was allowed to remain wide open all the time; gradient, 1 in 220 down; speed,

52.5 miles; time occupied, 55 secs.; distance run, 867 yards. In the final experiment all available means were used. When reversing the engine the steam was first shut off, then the lever pulled into back gear, and then steam was turned on again as in first experiment; gradient, level; speed, 52.5 miles; time, 50 secs.; distance, 787 yards. The weather was fair, and the rails slightly greased. Captain Tyler, in his report to the Board of Trade, states that the engine-driver of the mail train, who at present awaits trial on a charge of manslaughter, could not have acted so promptly as these who on the experimental train listened for the word of command. He adds that instead of 400 yards 800 yards should have been stated as the distance in which, with the assistance of the guard, he would have stopped his train.—*Iron.*

ENGINEERING STRUCTURES.

THE TUNNEL UNDER THE LONDON DOCKS.—The works on the East London Railway, by which the line will be extended from the present terminus at Wapping to the Liverpool Street Station of the Great Eastern Company, are now rapidly approaching completion, and it is expected that the extension line will shortly be opened for traffic, when there will be through communication between Liverpool Street and New Cross, where the line forms a junction with the London and Brighton and the South-Eastern lines. The most formidable engineering portion of the works is the tunnel under the eastern basin of the London Docks, which has just been completed. The water communication between one side of the basin is restored, and vessels of large tonnage may now be seen berthed in the basin immediately over the submarine railway which has been formed. Operations were carried on by means of coffer-dams and dredging trenches in the bottom of the dock until the London clay was reached. The driving of the piles and the construction of the walls of the coffer-dams was one of the most formidable portions of the work. The arches of the tunnel are of the ordinary horseshoe shape, built with seven rings of brick, and are surrounded with three feet of puddled clay. About two-thirds of the Shadwell Station are already completed, and the covered way northwards, in continuation, is also nearly all finished to about 50 feet north of Commercial Road. The retaining walls for the Whitechapel Station are also nearly finished, and the station itself will soon be completed. The line continues from Whitechapel Station to its junction with the Great Eastern line at Brick Lane, and the works at this point, which are comparatively light, are actively proceeding. The whole of the works have been designed by Sir John Hawkshaw, and are being caried out by Mr. Hunt, the resident engineer. The estimated cost of the works is set down at £500,000 per mile.

THE EIGHTY-ONE TON GUN.—The trial of the 81-ton gun took place the other week, at the butts within Woolwich Arsenal. The weight of the shot first fired was 1250 lb. and the charge of powder was 170 lb. It took twelve men to ram the charge home, and the shot was elevated to the mouth of the gun by hydraulic apparatus. The gun was fired by means of electricity. It was found that the shot had penetrated 45 feet of sand, and that the gun had a recoil of 23½ feet. A second shot was fired with a charge of 190 lb. The distance of penetration was over 50 feet, and the recoil 32 feet. The experiments were attended with great success, and no flaw was detected. So satisfied were the authorities of the Royal Gun Factories that the gun would prove a success that application has been made to the War Office for permission to construct four other guns of the same weight, and on precisely the same plans, and the preliminary forging and other preparations for these are already considerably advanced. This gun, which may be considered as an experimental piece of ordnance, is bored to a calibre of 14½ inches, and the walls are consequently much thicker than they will be when the tube is bored out to a diameter of 16 inches, while the strain upon the gun will of necessity be increased by every addition to the powder charge, which it is intended to augment gradually up to 300 lb. This is 60 lb. more than has yet been fired; but the strain has been carefully calculated and provided for with a margin of endurance to spare. So well has experience qualified the authorities to calculate results that the velocity attained by the gun in its its first round was foretold as 1390 feet per second, and it proved to be 1393 feet, within 3 feet of the velocity worked out. The length of the gun is 33 feet, and its diameter varies from about 2 feet at the muzzle to about 6 feet at the breech. Internally the bore measures 27 feet. The gun is not to be fired in its present state any more, but it has many more trials in store; its whole lifetime will, it is expected, be a series of trials, for, while its sister guns are being manufactured to go on service in the ironclad fleet, the four next for the turrets of the *Inflexible*, this, the original gun, will be devoted to experiments for the benefit of science.

WATER CONTRIVANCES IN INDIA.—The contrivances used in India for raising water, and for other purposes, are of a rather primitive kind, and our engineers have something to do to instruct natives in some of the simplest of our appliances. A pump, as we have it, is comparatively unknown, a kind of chain pump being used, with pots or leather bags attached. These primitive appliances sometimes frustrate the calculations of our engineers unaccustomed to them, and a few facts may be interesting, which Mr. Lowis D. A. Jackson, in his "Hydraulic Manual" furnishes us with. Our English mode of bucket baling is unknown in India. Instead of this, the natives use a flat kind of dish, made of leather, or wood bark, rendered water-tight, and stiffened by a frame. At each side cords are fastened, the ends of which are held by two men, who, by a quick mode of dipping and swinging, raise the water to the receptacle above. For clearing foundations where there

is swinging room it answers very well, the lift being generally about 5 ft. About 400 cubic feet of water per hour, or 20,000 gallons per day of eight hours, may be raised. The "beam and bucket" contrivance is a rather more scientific appliance for raising water by hand labor. It consists of a large earthenware vessel suspended at one end of a beam, which is rather thick, and so poised on a fulcrum by a counterweight at the other end, that the force of one man may easily raise the vessel when full.

The "picotah" of Southern India is a development of the principle; a long tree becomes in this case the balance-pole, which is worked by the weight of a man, who walks or runs up and down along the heavier arm of the lever. Another man manages the vessel, and the height of the lift is sometimes as much as 20 feet. The smaller appliance previously described we find can raise 82 cubic feet per hour, or about 4,100 gallons per day. Another similar contrivance is called the "dal," or "jantu." This consists of a wooden trough or gutter working on a pivot. It is worked usually by cords. As much as 21,000 gallons can be raised by this simple means in a day, and a lift of 5 feet, with two men, can be performed. Another very primitive method of raising water is by the "mot," which is a vessel made of ox-hide, bound to a wooden hoop, raised and lowered by a cord over a pulley by oxen, the animals performing the work by descending an inclined plane, and the bucket sometimes emptying itself by a catch cord. A more advanced mechanical appliance, like the ancient chain of pots used in Egypt, Syria, and by the Romans, is called the "Persian Wheel." It is composed of two endless ropes, united and passing over a wheel, the endless ropes hanging a little below the water in the well; earthen or leathern vessels are attached to the loop, which, after being filled, discharge into a trough through the vertical wheel, which is double. Motion is given by a vertical shaft, turned by bullocks. Our modern chain pumps are constructed on this plan. This last appliance is undoubtedly more economical as a labor-saving machine, and is used largely in Northern India. This appliance, lifting 40 feet, will raise 16,500 gallons per day, if it has a double chain of pots. All these methods, however, require a good coefficient of reduction to be applied, as an amount of work is lost by leakage, imperfect construction, &c.

ORDNANCE AND NAVAL.

THE "CASTALIA."—England's insular security is gone. Against an invading force we thought we had the iron-clads. What that amounted to the *Iron Duke* has shown. Still there was the *mal de mer*. But in the *Times* recently we find a jubilant epistle from a Frenchman, who came over from Calais in the *Castalia* in a heavy sea on the previous day, and whose only abnormal sensation during the voyage was a tendency to drowsiness. Capt. Dicey really appears to have achieved a great success, and left the *Bessemer* nowhere. All classes of Her Majesty's subjects, chief constructors at shipbuilding yards, artists, medical men, clergymen, lawyers, ladies, crowd the columns of the *Times*, and all with the same story, the absence of sea sickness on board the twin ship, owing to the absence of pitching, and the very slight rolling or tremulous motion experienced. Other minor causes of nausea, such as the smell of the engines and the closeness of the cabin, are reduced to a minimum. The only drawback is want of speed, which would probably be helped by the use of more powerful engines.

SUBMARINE OPERATIONS AND THE "VANGUARD."—The attempts to recover the *Vanguard* and the material sunk with her are likely to test to the utmost not only the skill and endurance of the divers, but also the numerous and ingenious appliances for submarine work that have been invented of late years. So far as these have been tried upon the sunken ironclad, they have apparently fallen far short of the necessities of the case. In the first place, although she only lies about seventy feet below low-tide level, the pressure of the superincumbent fluid appears to be too much for the strength of the most competent and well-accustomed divers. The two dockyard men who have been employed in this capacity, and who in powers of endurance and experience are said to be equal to any two members of their amphibious profession in the kingdom, can only remain under water at the depth named, for fifteen minutes at a time, and then come to the surface completely prostrated. The immense dead weight of the hull forbids any hope of raising it by the means which have often proved efficient in the case of lighter ships, and those engaged have spent weeks in a futile attempt to dislodge the vessel's iron masts. It is now proposed to place round these bands of dynamite, and blow them out of the hull, the effect of which will be farther to strain if not break it, and thus to render the success of future attempts to raise the ship still more problematical. She must also from her great weight sink to some extent in the sand on which she rests, however hard that may be, and there must be more or less of a silting process going on from currents even at the depth of eleven or twelve fathoms. In connection with these salvage operations there have been some very interesting experiments made in Cork Harbor with the Denayrouze submarine lamp. When at the bottom of the harbor, the diver who had charge of the lamp read aloud from a newspaper an account of the examination of the prow of the *Iron Duke*, which was distinctly heard through the Denayrouze speaking-tube, an adaptation of a species of popular entertainment at once novel and remarkable. This lamp, which can be lighted under water, is likely to prove one of the most useful aids to submarine operations that has yet been invented, and from the way in which fishes and other marine creatures are attracted to light, it is probable that had the diver in the instance noted been in a less confined locality, he would, like St. Anthony, have had a much larger audience under than above the surface of the water.

BOOK NOTICES

ANNUAL REPORT OF HER MAJESTY'S INSPECTOR OF GUNPOWDER WORKS. For sale by D. Van Nostrand. Price 50 cts.

This is but little else than a collection of statistics relating to the manufactories of the United Kingdom, together with brief summaries of the laws regulating such establishments.

Gunpowder is used in a generic sense, and includes all manufactured explosives.

REPORTS OF THE ROYAL COMMISSION ON SCIENTIFIC INSTRUCTION AND THE ADVANCEMENT OF SCIENCE. The Sixth, Seventh and Eighth Reports. Parliamentary Blue Books.

These reports contain much that is valuable to educators everywhere. Aside from the valuable essays on special branches of education, there is a mine of information in the exhibition of the entire list of duties of instructors and pupils in the schools and colleges of Great Britain. The curriculum of studies of each is given, together, in many instances, with complete sets of examination questions for entering and graduating pupils.

The Apparatus is specified, by means of which the separate topics of Chemistry or Physics are illustrated. Many valuable suggestions to instructors are afforded, especially in the Sixth Report.

CHAMBER'S ELEMENTARY SCIENCE MANUALS. London and Edinburgh: W. & R. Chambers. For sale by D. Van Nostrand. Price 50 cts. each.

These petite treatises are designed to present a fair outline of the different branches of science. Each one is about what would be expected under an article of its proper heading in a large encyclopædia. The authors are prominent men, and are accustomed to presenting scientific truths in a way calculated to instruct.

The series as at present published embrace subjects as follows:

Chemistry, by Alex. Crum Brown, M.D.
Electricity, by John Cook, M. D.
Astronomy, by Andrew Findlater, LL. D.
Language, by Andrew Findlater, LL. D.
Geology, by James Geike, F. R. S.

DISCOVERIES AND INVENTIONS OF THE NINETEENTH CENTURY. By ROBERT ROUTLEDGE, F. C. S. London: George Routledge & Sons. For sale by D. Van Nostrand. Price $3.50.

This attractive looking book belongs to the class of popular scientific works whose design is to present in pleasing form a kind of information that many people would not otherwise get. The general style of the book is that of Pepper's Play-Books, and, indeed, some of the illustrations are borrowed from those well known repositories of easy science. But the present work covers a somewhat wider range of subjects, and, moreover, deals with later inventions, such as the "Sand-blast" and the "Bessemer Steamer."

The illustrations are very numerous, and quite good. We judge that it will prove to be a good gift-book for boys during the coming season.

TIMBER AND TIMBER TREES. By THOMAS LASLETT. London: Macmillan & Co. For sale by D. Van Nostrand. Price $3.50.

This book presents the substance of a course of lectures delivered before the Royal School of Naval Architecture at South Kensington.

As a matter of course, the qualities of the various kinds of timber are specially treated of, while the natural history of the trees is very briefly treated.

We have never seen before such a collection of tables of strength of timber as here; and all seem carefully arranged from fairly tried experiments. There are but few illustrations, but the treatise is full of interesting and valuable matter to all who are concerned in the selection, use or preservation of timber.

VAN NOSTRAND'S SCIENCE SERIES, No. 19. STRENGTH OF BEAMS UNDER TRANSVERSE LOADS. By Prof. W. ALLAN. New York: D. Van Nostrand. Price 50 cts.

This important subject is treated to some extent in the standard works on Mechanics. It is too briefly disposed of in such treatises to fully satisfy the wants of a large number to whom the subject is of vital importance.

In too many cases the higher mathematics are employed, and thus the usefulness of much that is well written is lost to the young engineer who is not well up in calculus.

Prof. Allan has treated this subject with reference to the needs of pupils, who prefer from necessity or otherwise, the simplest demonstration that can be considered complete. Graphic methods are largely employed, and illustrative examples are added as an aid to the student. The illustrations are exceedingly abundant and well executed.

The readers of the Magazine have been made acquainted with the quality of their excellent treatise by the published articles in the current volume.

DISCOURSES ON ARCHITECTURE. By EUGENE EMMANUEL VIOLLET-LE-DUC. Translated by Henry Van Brunt. Boston: James R. Osgood & Company. Sold by Van Nostrand. Price $8.00.

Nearly all of our standard works on architecture are from English sources, and of course inculcate views more or less influenced by national pride, and in too many instances strongly tinged with national jealousy.

The instruction books in particular have presented quite exclusively the rules and designs of English writers and architects.

In this new treatise, we have at least the ideas of a writer who occupies a different stand point, and so far as prejudice is concerned, it is at least not of the kind which is possible in our standard works. That the author is a competent man for the task of presenting the principles of design, may be judged from his record both as architect and author.

The translator says of him: "And here at last is a man who has studied, measured, analyzed, and drawn Greek and Roman monuments in Italy and the Greek colonies, certainly with singular fidelity and intelligence; who has rebuilt and completed the great Gothic Chateau of Pierrefonds, built the town halls

of Narbonne and St. Antonin, restored numerous churches; constructed the fleche and sacristy of the Cathedral of Paris; repaired the fortifications of Carcassone; architect of the works on the Cathedrals of Laon, Sens and Amiens, and the Abbeys of St. Denis and Vézelay; author of the exhaustive 'Dictionaire Raisonnie de l'Arohitecture Frangaise, du Xe au XVIe Sciecles,' and other works of large research. Thus equipped, M. Viollet-le-Duc appears upon the scene and endeavors to set forth the true principles of design. * * We do not mean to assert that the author has succeeded in all things, but we think it important to give a new publicity to this honest and earnest effort, and to place it side by side with similar essays of literary men and amateurs, that it may do its work with theirs."

The book is in elegant style, and is finely illustrated.

THE NEW METHOD OF GRAPHICAL STATICS. By A. J. DU BOIS, Ph. D., Prof. of Civil Engineering, Lehigh University. New York: D. Van Nostrand. Price $2.00.

The method of Graphical Statics is less widely known in this country than in either France, Germany or Great Britain. In each of these countries text-books expounding the principles of the method are easily obtained. Here the demand for such treatises is just beginning to be heard; and already the value of this branch of science is recognized by the use made by instructors of such published articles as have appeared in this and one or two other periodicals.

Prof. Du Bois is first in the field to present to American Students a systematic exposition of the elements of this important subject.

Beginning with the rudimentary steps, the system is quite completely set forth, so that the learner can easily master the subject without aid from an instructor, providing always that he is familiar with elementary plane geometry and the elements of mechanics. The fundamental principles once learned, the applications to the important problems of engineering are exceedingly easy and rapid.

In the opening chapters of the present treatise, the author thus discourses upon the characteristics of the method:

"The object of the following pages is to call more general attention to a new method for the graphical solution of statical problems, which has during the last ten years, mainly in Germany, been gradually developed and perfected, and which offers to the architect, civil engineer, and constructor, a simple, swift, and accurate means for the investigation of a great number of practical questions. When once thoroughly understood and familiarized, it will be found greatly superior to the graphic methods at present in general use. Thus, for instance, in the determination of the *centre of gravity* and *moment of inertia* of areas and solids; of the resultant of forces either in space or in the same plane, and having the same or different points of application, as also in the resolution of forces generally, the method alluded to will be found of easy and universal application. When applied to determine the strains in the various members of a roof truss, bridge girder, or similar framed structure, it furnishes a system of 'diagraming' which can be applied independently of any special assumptions as to load distribution, which gives the strain in each member by a single line, which is simple and rapid of execution, and which checks its own accuracy. In its application to '*continuous girders*' it furnishes the *only* method of complete solution for variable loading, without calling in the aid of the higher analysis, or having recourse to intricate formulæ and wearisome calculations. Thus, a girder continuous over three or more supports, at different elevations, and sustaining a 'concentrated load' at any point, can be investigated with nearly the same ease and accuracy as one resting upon only two supports. Here especially those already familiar with the analytical method can, by a union of the two, greatly shorten the time and labor usually consumed in such cases.

"To Prof. Mohr, of the Stuttgart Polytechnicum, the new method owes its origin, as well as many of its most important improvements and extensions. But it was not till 1866 that the complete and systematic presentation of the subject by Culmann directed general attention to the subject, and excited general interest.

"During the eight years which have since elapsed, the method has been considerably extended, notably in the treatment of continuous girders above referred to, and the new edition of Culmann's original work, which is soon to appear, and which has been so long promised, is looked forward to in Germany with considerable interest.

"Admirable as Culmann's treatment of the subject undoubtedly is, still for a long time this interesting and useful method failed to meet with that appreciation and recognition from professional men to which it had just claims; partly, perhaps, because of a natural disinclination in old practitioners to relinquish well known and familiar methods, and partly because the treatment of Culmann required for its comprehension a knowledge of the so-called 'Modern Geometry,' or *Theory of Transversals.*

"This method of treatment is, however, by no means necessary. The system admits of a clear and logical development, which can be followed and apprehended by any one familiar with the elements of geometry as generally taught; and to give in just such a manner the outlines of the subject, indicating its most important applications, and thus to bring it within the reach of those in this country for whose benefit it seems so especially designed, is the purpose of these pages."

The book is neatly printed, with the plates so folded in as to open out in the best manner for the references which are certainly necessary.

It is already in demand for class use.

EXAMPLES ON HEAT. By R. E. Day, M. A. Longmans & Co. London, 1875.

There is no doubt that, in order to give a real, practical character to the teachings of

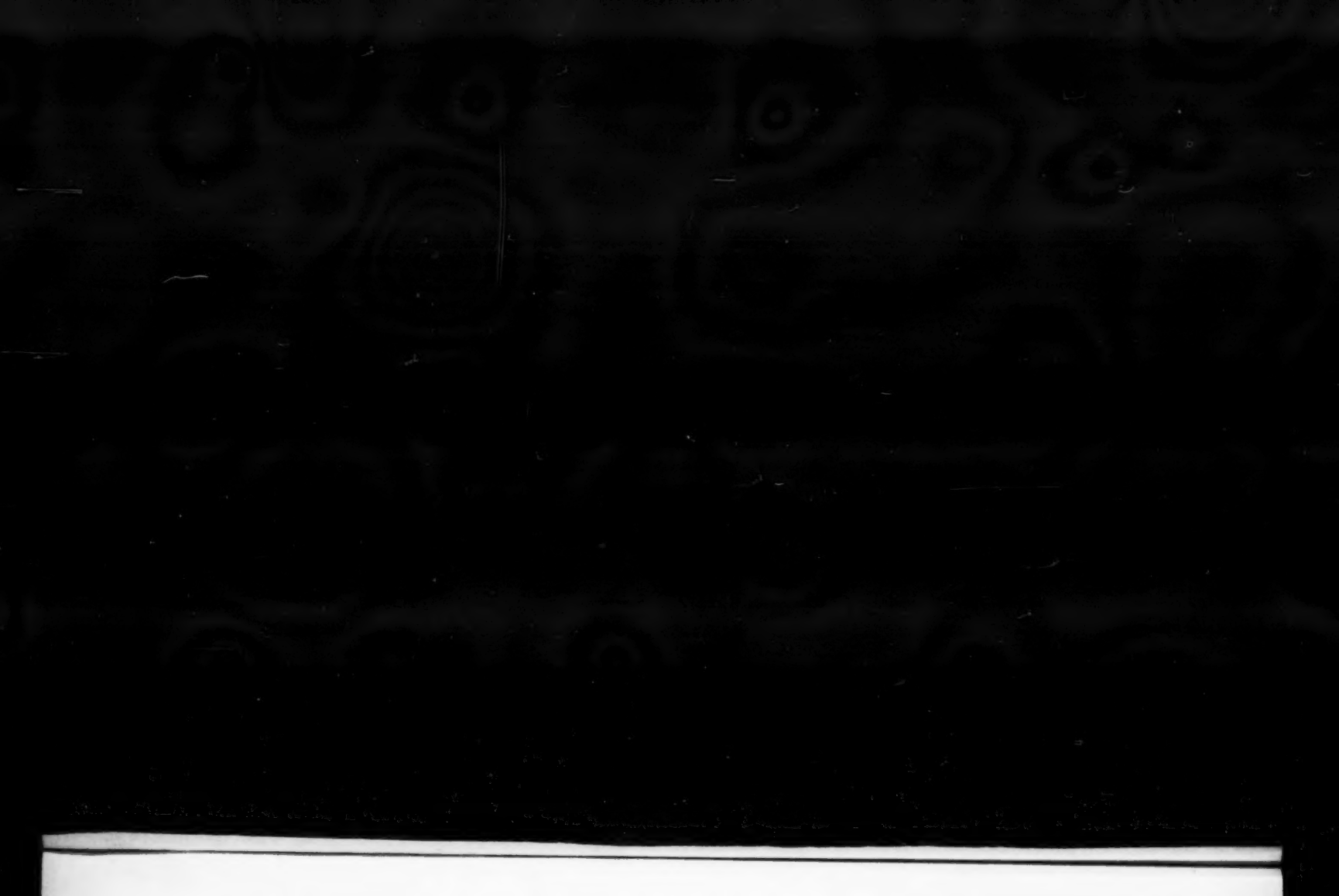
physical science in our schools and colleges, the working by the students themselves of such problems as they would actually encounter in the every-day life of engineering or other pursuits is of great importance, and in this respect, we are sorry to say, our scientific class-books have hitherto been very deficient. It is in consequence almost impossible for a lecturer, when discussing the expression of any physical law in a mathematical formula, to go into it except in general terms; and between this and the actual use of it for practical purposes there is a very wide gap. A thorough acquaintance with such formulæ can scarcely be acquired by the student from merely reading about them, or seeing them written on a black board, whereas, if he has once worked out numerically a few examples of them, he acquires confidence in their use, and a real grasp of their actual signification. This small volume, which has just been published by Messrs. Longmans, deserves a welcome for these reasons, its object being to familiarize the student with the laws of heat by affording him sufficient exercise, not so much in the manipulation of algebraical expressions, as in the numerical solution of practical problems. We notice, as of special interest to engineers, that it contains examples of the conduction of heat in boiler-plates and the expansion of railway metals, while there are a large number of problems which involve the idea of the connection between thermal energy and mechanical force. As the answers are given to all the questions, the working of the problems is put within the reach of private students.

The value of the book, however, would have been materially increased if the several sections of examples into which it is divided had been headed with the formulæ applying to them, and we advise the author to add them to the next edition. The little work gives evidence of having been most carefully prepared, and we can, on the whole, recommend it confidently to all who, whether as teachers or learners, are desirous of gaining a real, working knowledge of the laws of heat. We trust that what the author has thus succeeded in doing to facilitate the study of heat, he will repeat for the other branches of physical science.—*Engineer.*

MISCELLANEOUS.

Talc has been recommended by MM. Vigier and Aragon for the prevention of incrustation in boilers. It is used on the Paris and Lyons Railway, and it is stated that the quantity of talc introduced into the boiler is about one-tenth of the weight of deposit accumulated between two consecutive blow-offs. It is stated not only to prevent but to loosen and remove old incrustation.

Belgian Iron Trade.—The manufactured iron trade of Belgium is reviving, in consequence of the low rates of pig-iron, and the rolling mills are getting again into work. At Acoz a new rolling and flatting mill—a third one—has been opened, for the manufacture of merchant iron of every variety, in view of the demand likely to arise from the exhaustion of the present stocks of rails. The new mill can turn out 40 tons of finished iron per day of twenty-four hours. The Société de Sclessen is said to be getting 100 kilos. of pig-iron with 97 kilos. of coke, being the first furnace in Belgium which has obtained such a result.

A New Metal.—Gallium is the name given, "in honor of France," to a new element which has been discovered by M. Lecoq, an amateur *savant*, of Bois-Baudran, Cognac. The celebrated chemist, Wurtz, presented to the Académie des Sciences, in its sitting of September 20th, a note on the part of M. Lecoq, announcing the discovery, particulars of which had been communicated under seal as far back as August 27th. This new element has not yet been isolated, and has not therefore been seen by any one; its physical characteristics remain so far unknown. It is an analogue of zinc and cadmium, of which metals it is an alloy, and was found in a blende from Pietrafita, Spain. The forms under which it is known, so far, are those of the chloride and sulphate. The discoverer is a student of the phenomena of the spectroscope, and it was in the course of his observations that the new metal presented itself, its character being revealed by a spectrum which no simple body had ever given. Two lines, one much brighter than the other, both situated in the violet—the region occupied by the brightest lines of the zinc—were noticed, the place of the former line being at the 417th degree of the scale of lines, and the other at the 404th.

The affinities which gallium has with zinc are declared by chemical analysis as well as by its spectrum. Like zinc it is not thrown down from solution in hydrochloric acid by sulphuretted hydrogen; and preserves its analogy with zinc by being precipitated by the same gas from an acetic acid solution. Under these conditions it is obtained before the zinc, and on fractionation, the two are got separately. Like zinc, the new metal gives a white precipitate with the sulphide of ammonium. On immersing a piece of zinc in a solution of the new metal it separates and comes out, not in a metallic form, but under that of an oxyde, precisely as aluminum does under similar circumstances. The analogy with aluminum, however, is not long sustained, for if a small dose of ammonia precipitates the gallium an excess redissolves it. Up to the present time, only a very small quantity of gallium has been obtained, but M. Wurtz, who presented the paper, has given the Academy tubes of solution for experiment; and on asking for a commission to examine into the question and to place gallium on the list of simple bodies, the Academy named M. Wurtz himself, joining with him M. Frémy. The actual number of known elements is 63, 47 of which are metals and 16 metalloids. If the new element takes the place claimed for it, France will have obtained an honor equal to that of England which discovered thallium, and approximative to that of Germany, the discoverer of casium and rubidium.